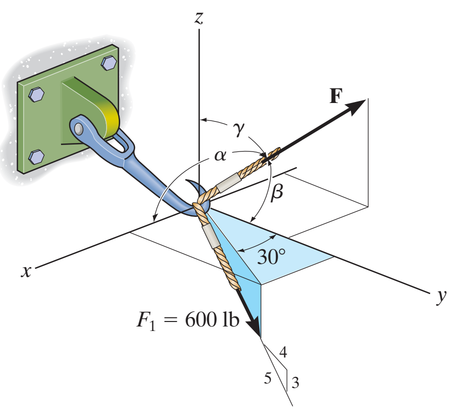
2–71. If $\alpha = 120°$, $\beta < 90°$, $\gamma = 60°$, and $F = 400$ lb, determine the magnitude and coordinate direction angles of the resultant force acting on the hook.



Force Vectors: Since $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$, then $\cos\beta = \pm\sqrt{1 - \cos^2 120° - \cos^2 60°} = \pm 0.7071$. However, it is required that $\beta < 90°$, thus, $\beta = \cos^{-1}(0.7071) = 45°$. By resolving $\mathbf{F}_1$ and $\mathbf{F}_2$ into their x, y, and z components, as shown in Figs. a and b, respectively, $\mathbf{F}_1$ and $\mathbf{F}_2$, can be expressed in Cartesian vector form as

$$\mathbf{F}_1 = 600\left(\frac{4}{5}\right)\sin 30°(+\mathbf{i}) + 600\left(\frac{4}{5}\right)\cos 30°(+\mathbf{j}) + 600\left(\frac{3}{5}\right)(-\mathbf{k})$$
$$= \{240\mathbf{i} + 415.69\mathbf{j} - 360\mathbf{k}\}\text{ lb}$$
$$\mathbf{F} = 400\cos 120°\mathbf{i} + 400\cos 45°\mathbf{j} + 400\cos 60°\mathbf{k}$$
$$= \{-200\mathbf{i} + 282.84\mathbf{j} + 200\mathbf{k}\}\text{ lb}$$

Resultant Force: By adding $\mathbf{F}_1$ and $\mathbf{F}$ vectorally, we obtain $\mathbf{F}_R$.

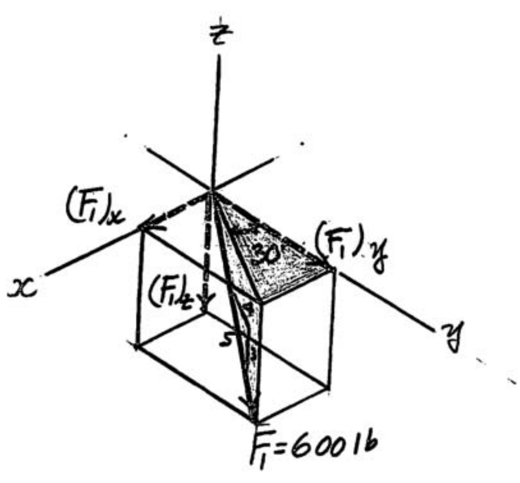
$$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}$$
$$= (240\mathbf{i} + 415.69\mathbf{j} - 360\mathbf{k}) + (-200\mathbf{i} + 282.84\mathbf{j} + 200\mathbf{k})$$
$$= \{40\mathbf{i} + 698.53\mathbf{j} - 160\mathbf{k}\}\text{ lb}$$

The magnitude of $\mathbf{F}_R$ is

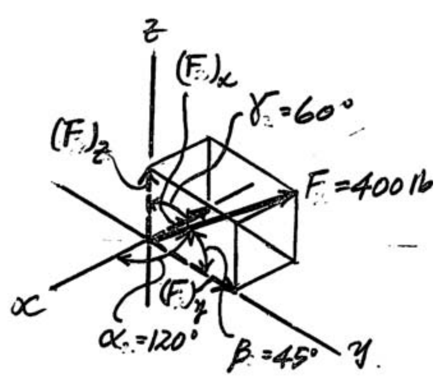
$$F_R = \sqrt{(F_R)_x^2 + (F_R)_y^2 + (F_R)_z^2}$$
$$= \sqrt{(40)^2 + (698.53)^2 + (-160)^2} = 717.74\text{ lb} = 718\text{ lb} \qquad \textbf{Ans.}$$

The coordinate direction angles of $\mathbf{F}_R$ are

$$\alpha = \cos^{-1}\left[\frac{(F_R)_x}{F_R}\right] = \cos^{-1}\left(\frac{40}{717.74}\right) = 86.8° \qquad \textbf{Ans.}$$
$$\beta = \cos^{-1}\left[\frac{(F_R)_y}{F_R}\right] = \cos^{-1}\left(\frac{698.53}{717.74}\right) = 13.3° \qquad \textbf{Ans.}$$
$$\gamma = \cos^{-1}\left[\frac{(F_R)_z}{F_R}\right] = \cos^{-1}\left(\frac{-160}{717.74}\right) = 103° \qquad \textbf{Ans.}$$

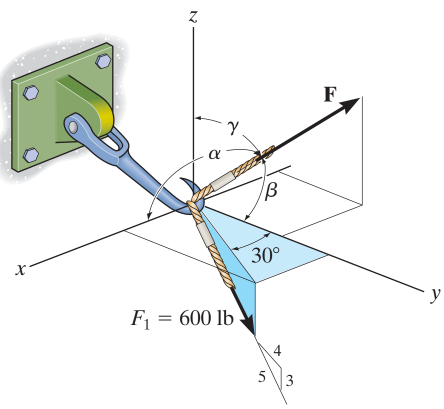


(a)



(b)

***2–72.** If the resultant force acting on the hook is $\mathbf{F}_R = \{-200\mathbf{i} + 800\mathbf{j} + 150\mathbf{k}\}$ lb, determine the magnitude and coordinate direction angles of **F**.



Force Vectors: By resolving $\mathbf{F}_1$ and $\mathbf{F}$ into their x, y, and z components, as shown in Figs. *a* and *b*, respectively, $\mathbf{F}_1$ and $\mathbf{F}_2$ can be expressed in Cartesian vector form as

$$\mathbf{F}_1 = 600\left(\frac{4}{5}\right)\sin 30°(+\mathbf{i}) + 600\left(\frac{4}{5}\right)\cos 30°(+\mathbf{j}) + 600\left(\frac{3}{5}\right)(-\mathbf{k})$$
$$= \{240\mathbf{i} + 415.69\mathbf{j} - 360\mathbf{k}\}\text{ lb}$$
$$\mathbf{F} = F\cos\alpha\mathbf{i} + F\cos\beta\mathbf{j} + F\cos\gamma\mathbf{k}$$

Resultant Force: By adding $\mathbf{F}_1$ and $\mathbf{F}_2$ vectorally, we obtain $\mathbf{F}_R$. Thus,

$$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}$$
$$-200\mathbf{i} + 800\mathbf{j} + 150\mathbf{k} = (240\mathbf{i} + 415.69\mathbf{j} - 360\mathbf{k}) + (F\cos\theta_x\mathbf{i} + F\cos\theta_y\mathbf{j} + F\cos\theta_z\mathbf{k})$$
$$-200\mathbf{i} + 800\mathbf{j} + 150\mathbf{k} = (240 + F\cos\alpha)\mathbf{i} + (415.69 + F\cos\beta)\mathbf{j} + (F\cos\gamma - 360)\mathbf{k}$$

Equating the **i**, **j**, and **k** components, we have

$$-200 = 240 + F\cos\theta_x$$
$$F\cos\alpha = -440 \qquad (1)$$

$$800 = 415.69 + F\cos\beta$$
$$F\cos\beta = 384.31 \qquad (2)$$

$$150 = F\cos\gamma - 360$$
$$F\cos\gamma = 510 \qquad (3)$$

Squaring and then adding Eqs. (1), (2), and (3), yields

$$F^2(\cos^2\alpha + \cos^2\beta + \cos^2\gamma) = 601392.49 \qquad (4)$$

However, $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$. Thus, from Eq. (4)

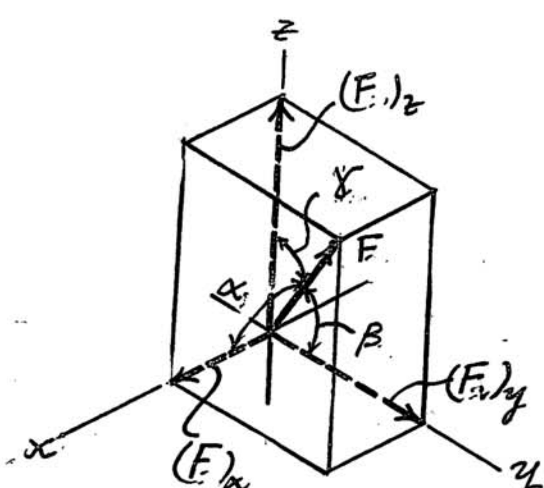
$$F = 775.49\text{ N} = 775\text{ N} \qquad \textbf{Ans.}$$

Substituting $F = 775.49$ N into Eqs. (1), (2), and (3), yields

$$\alpha = 125° \qquad \beta = 60.3° \qquad \gamma = 48.9° \qquad \textbf{Ans.}$$

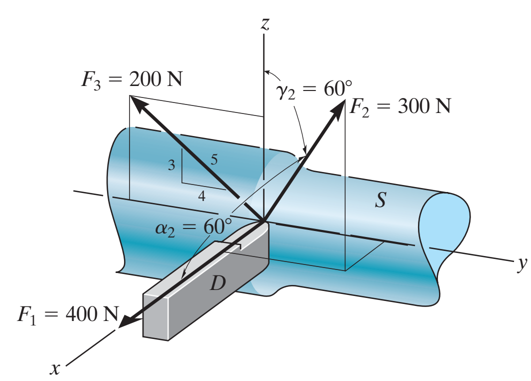
see Prob. 2-71a

(a)



(b)

•2–73. The shaft S exerts three force components on the die D. Find the magnitude and coordinate direction angles of the resultant force. Force $\mathbf{F}_2$ acts within the octant shown.



$\mathbf{F}_1 = 400\,\mathbf{i}$

Since $\cos^2 60° + \cos^2 \beta_2 + \cos^2 60° = 1$

Solving for the positive root, $\beta_2 = 45°$

$\mathbf{F}_2 = 300 \cos 60°\,\mathbf{i} + 300 \cos 45°\,\mathbf{j} + 300 \cos 60°\,\mathbf{k}$

$= 150\,\mathbf{i} + 212.1\,\mathbf{j} + 150\,\mathbf{k}$

$\mathbf{F}_3 = -200\left(\frac{4}{5}\right)\mathbf{j} + 200\left(\frac{3}{5}\right)\mathbf{k}$

$= -160\,\mathbf{j} + 120\,\mathbf{k}$

Then

$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = 550\,\mathbf{i} + 52.1\,\mathbf{j} + 270\,\mathbf{k}$

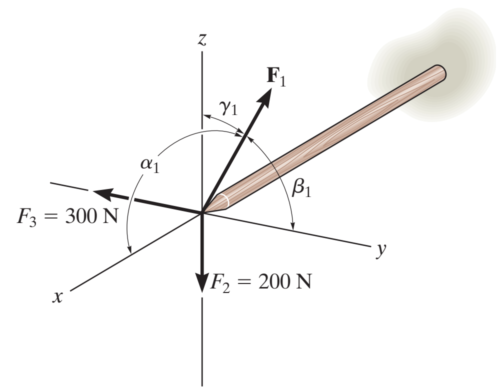
$F_R = \sqrt{(550)^2 + (52.1)^2 + (270)^2} = 614.9\text{ N} = 615\text{ N}$ **Ans**

$\alpha = \cos^{-1}\left(\frac{550}{614.9}\right) = 26.6°$ **Ans**

$\beta = \cos^{-1}\left(\frac{52.1}{614.9}\right) = 85.1°$ **Ans**

$\gamma = \cos^{-1}\left(\frac{270}{614.9}\right) = 64.0°$ **Ans**

2–74. The mast is subjected to the three forces shown. Determine the coordinate direction angles $\alpha_1, \beta_1, \gamma_1$ of $\mathbf{F}_1$ so that the resultant force acting on the mast is $\mathbf{F}_R = \{350\mathbf{i}\}$ N.



$\mathbf{F}_1 = 500 \cos\alpha_1\,\mathbf{i} + 500\cos\beta_1\,\mathbf{j} + 500 \cos\gamma_1\,\mathbf{k}$

$\mathbf{F}_R = \mathbf{F}_1 + (-300\mathbf{j}) + (-200\mathbf{k})$

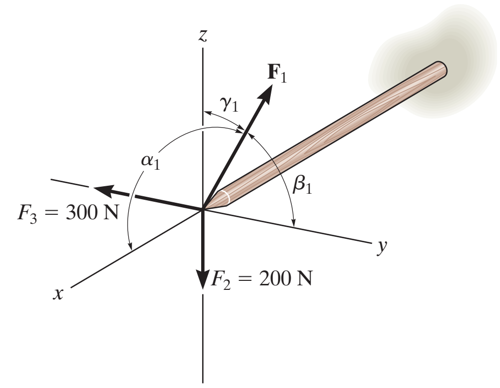
$350\mathbf{i} = 500 \cos\alpha_1\,\mathbf{i} + (500 \cos\beta_1 - 300)\mathbf{j} + (500 \cos\gamma_1 - 200)\mathbf{k}$

$350 = 500 \cos\alpha_1;$ $\alpha_1 = 45.6°$ **Ans**

$0 = 500\cos\beta_1 - 300;$ $\beta_1 = 53.1°$ **Ans**

$0 = 500\cos\gamma_1 - 200;$ $\gamma_1 = 66.4°$ **Ans**

2–75. The mast is subjected to the three forces shown. Determine the coordinate direction angles $\alpha_1, \beta_1, \gamma_1$ of $\mathbf{F}_1$ so that the resultant force acting on the mast is zero.



$\mathbf{F}_1 = \{500\cos\alpha_1\,\mathbf{i} + 500\cos\beta_1\,\mathbf{j} + 500\cos\gamma_1\,\mathbf{k}\}$ N

$\mathbf{F}_2 = \{-200\mathbf{k}\}$ N

$\mathbf{F}_3 = \{-300\mathbf{j}\}$ N

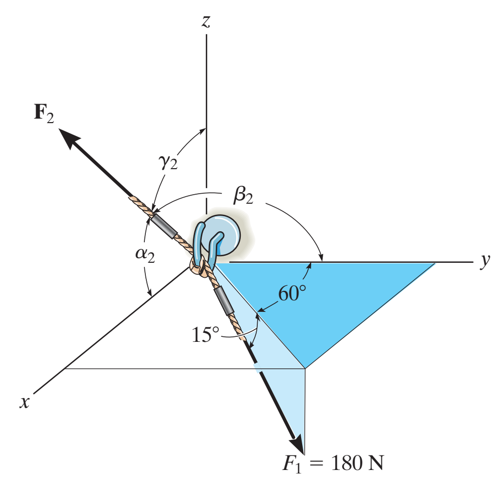
$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 = \mathbf{0}$

$500\cos\alpha_1 = 0;\qquad \alpha_1 = 90°$ **Ans**

$500\cos\beta_1 = 300;\qquad \beta_1 = 53.1°$ **Ans**

$500\cos\gamma_1 = 200;\qquad \gamma_1 = 66.4°$ **Ans**

***2–76.** Determine the magnitude and coordinate direction angles of $\mathbf{F}_2$ so that the resultant of the two forces acts along the positive x axis and has a magnitude of 500 N.



$\mathbf{F}_1 = (180\cos 15°)\sin 60°\,\mathbf{i} + (180\cos 15°)\cos 60°\,\mathbf{j} - 180\sin 15°\,\mathbf{k}$

$= 150.57\,\mathbf{i} + 86.93\,\mathbf{j} - 46.59\,\mathbf{k}$

$\mathbf{F}_2 = F_2\cos\alpha_2\,\mathbf{i} + F_2\cos\beta_2\,\mathbf{j} + F_2\cos\gamma_2\,\mathbf{k}$

$\mathbf{F}_R = \{500\,\mathbf{i}\}$ N

$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2$

i components :

$500 = 150.57 + F_2\cos\alpha_2$

$F_{2x} = F_2\cos\alpha_2 = 349.43$

j components :

$0 = 86.93 + F_2\cos\beta_2$

$F_{2y} = F_2\cos\beta_2 = -86.93$

k components :

$0 = -46.59 + F_2\cos\gamma_2$

$F_{2z} = F_2\cos\gamma_2 = 46.59$

Thus,

$F_2 = \sqrt{F_{2x}^2 + F_{2y}^2 + F_{2z}^2} = \sqrt{(349.43)^2 + (-86.93)^2 + (46.59)^2}$

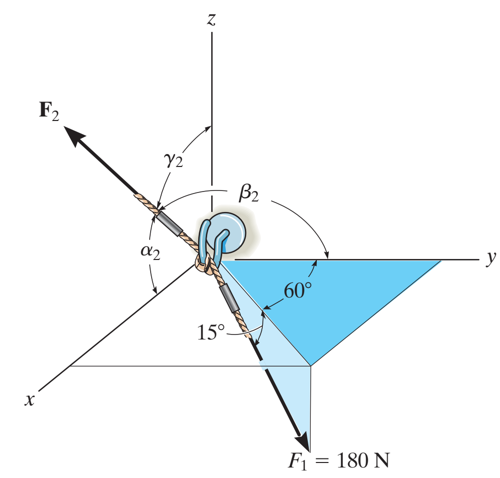
$F_2 = 363$ N **Ans**

$\alpha_2 = 15.8°$ **Ans**

$\beta_2 = 104°$ **Ans**

$\gamma_2 = 82.6°$ **Ans**

•2–77. Determine the magnitude and coordinate direction angles of $\mathbf{F}_2$ so that the resultant of the two forces is zero.



$\mathbf{F}_1 = (180 \cos 15°) \sin 60° \,\mathbf{i} + (180 \cos 15°) \cos 60° \,\mathbf{j} - 180 \sin 15° \,\mathbf{k}$

$= 150.57 \,\mathbf{i} + 86.93 \,\mathbf{j} - 46.59 \,\mathbf{k}$

$\mathbf{F}_2 = F_2 \cos \alpha_2 \,\mathbf{i} + F_2 \cos \beta_2 \,\mathbf{j} + F_2 \cos \gamma_2 \,\mathbf{k}$

$\mathbf{F}_R = \mathbf{0}$

i components :

$$0 = 150.57 + F_2 \cos \alpha_2$$

$F_2 \cos\alpha_2 = -150.57$

j components :

$$0 = 86.93 + F_2 \cos \beta_2$$

$F_2 \cos \beta_2 = -86.93$

k components :

$$0 = -46.59 + F_2 \cos \gamma_2$$

$F_2 \cos \gamma_2 = 46.59$

$$F_2 = \sqrt{(-150.57)^2 + (-86.93)^2 + (46.59)^2}$$

Solving,

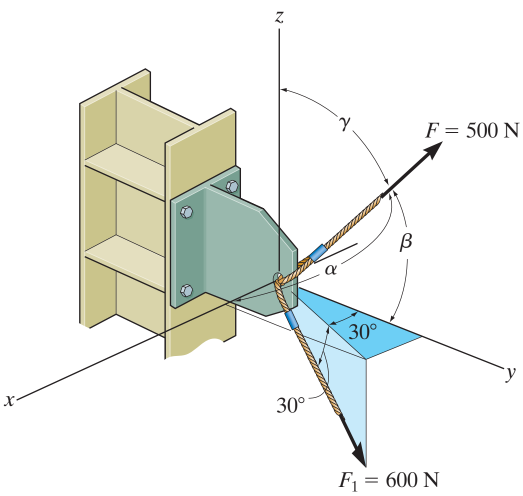
$F_2 = 180 \text{ N}$ **Ans**

$\alpha_2 = 147°$ **Ans**

$\beta_2 = 119°$ **Ans**

$\gamma_2 = 75.0°$ **Ans**

2–78. If the resultant force acting on the bracket is directed along the positive y axis, determine the magnitude of the resultant force and the coordinate direction angles of $\mathbf{F}$ so that $\beta < 90°$.



Force Vectors: By resolving $\mathbf{F}_1$ and $\mathbf{F}$ into their x, y, and z components, as shown in Figs. a and b, respectively, $\mathbf{F}_1$ and $\mathbf{F}$ can be expressed in Cartesian vector form as

$$\mathbf{F}_1 = 600\cos 30°\sin 30°(+\mathbf{i}) + 600\cos 30°\cos 30°(+\mathbf{j}) + 600\sin 30°(-\mathbf{k})$$
$$= \{259.81\mathbf{i} + 450\mathbf{j} - 300\mathbf{k}\}\text{ N}$$
$$\mathbf{F} = 500\cos\alpha\mathbf{i} + 500\cos\beta\mathbf{j} + 500\cos\gamma\mathbf{k}$$

Since the resultant force $\mathbf{F}_R$ is directed towards the positive y axis, then

$$\mathbf{F}_R = F_R\mathbf{j}$$

Resultant Force:

$$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}$$
$$F_R\mathbf{j} = (259.81\mathbf{i} + 450\mathbf{j} - 300\mathbf{k}) + (500\cos\theta_x\mathbf{i} + 500\cos\theta_y\mathbf{j} + 500\cos\theta_z\mathbf{k})$$
$$F_R\mathbf{j} = (259.81 + 500\cos\alpha)\mathbf{i} + (450 + 500\cos\beta)\mathbf{j} + (500\cos\gamma - 300)\mathbf{k}$$

Equating the $\mathbf{i}$, $\mathbf{j}$, and $\mathbf{k}$ components,

$$0 = 259.81 + 500\cos\alpha$$
$$\alpha = 121.31° = 121° \qquad \textbf{Ans.}$$
$$F_R = 450 + 500\cos\beta \qquad (1)$$

$$0 = 500\cos\gamma - 300$$
$$\gamma = 53.13° = 53.1° \qquad \textbf{Ans.}$$

However, since $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$, $\alpha = 121.31°$, and $\gamma = 53.13°$,

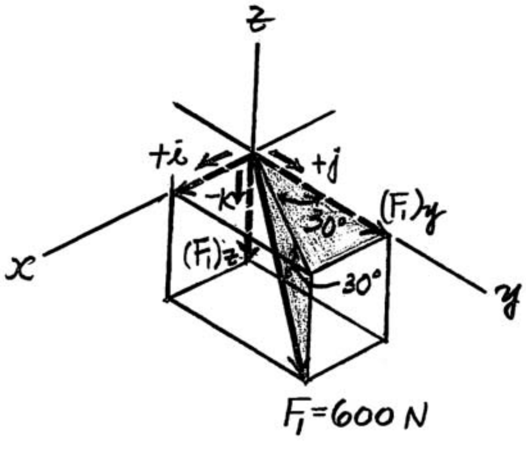
$$\cos\beta = \pm\sqrt{1 - \cos^2 121.31° - \cos^2 53.13°} = \pm 0.6083$$

If we substitute $\cos\beta = 0.6083$ into Eq. (1),

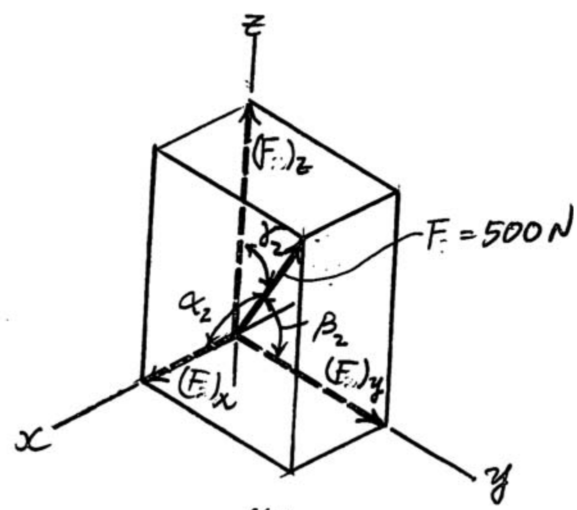
$$F_R = 450 + 500(0.6083) = 754\text{ N} \qquad \textbf{Ans.}$$

and

$$\beta = \cos^{-1}(0.6083) = 52.5° \qquad \textbf{Ans.}$$

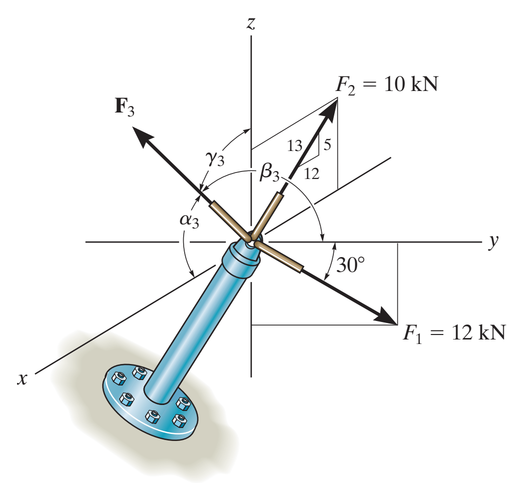


(a)



(b)

2–79. Specify the magnitude of $\mathbf{F}_3$ and its coordinate direction angles $\alpha_3, \beta_3, \gamma_3$ so that the resultant force $\mathbf{F}_R = \{9\mathbf{j}\}$ kN.



$$\mathbf{F}_1 = 12\cos 30^\circ\,\mathbf{j} - 12\sin 30^\circ\,\mathbf{k} = 10.392\,\mathbf{j} - 6\,\mathbf{k}$$

$$\mathbf{F}_2 = -\frac{12}{13}(10)\,\mathbf{i} + \frac{5}{13}(10)\,\mathbf{k} = -9.231\,\mathbf{i} + 3.846\,\mathbf{k}$$

Require

$$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3$$

$$9\,\mathbf{j} = 10.392\,\mathbf{j} - 6\,\mathbf{k} - 9.231\,\mathbf{i} + 3.846\,\mathbf{k} + \mathbf{F}_3$$

$$\mathbf{F}_3 = 9.231\,\mathbf{i} - 1.392\,\mathbf{j} + 2.154\,\mathbf{k}$$

Hence,

$$F_3 = \sqrt{(9.231)^2 + (-1.392)^2 + (2.154)^2}$$

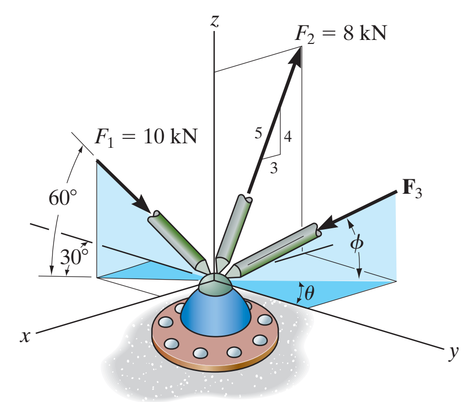
$$F_3 = 9.581\text{ kN} = 9.58\text{ kN} \qquad \textbf{Ans}$$

$$\alpha_3 = \cos^{-1}\left(\frac{9.231}{9.581}\right) = 15.5^\circ \qquad \textbf{Ans}$$

$$\beta_3 = \cos^{-1}\left(\frac{-1.392}{9.581}\right) = 98.4^\circ \qquad \textbf{Ans}$$

$$\gamma_3 = \cos^{-1}\left(\frac{2.154}{9.581}\right) = 77.0^\circ \qquad \textbf{Ans}$$

***2–80.** If $F_3 = 9$ kN, $\theta = 30°$, and $\phi = 45°$, determine the magnitude and coordinate direction angles of the resultant force acting on the ball-and-socket joint.



Force Vectors: By resolving $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ into their x, y, and z components, as shown in Figs. respectively, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ can be expressed in Cartesian vector form as

$$\mathbf{F}_1 = 10\cos 60°\sin 30°(-\mathbf{i}) + 10\cos 60°\cos 30°(+\mathbf{j}) + 10\sin 60°(-\mathbf{k})$$
$$= \{-2.5\mathbf{i} + 4.330\mathbf{j} - 8.660\mathbf{k}\}\text{ kN}$$

$$\mathbf{F}_2 = 8\left(\frac{3}{5}\right)(-\mathbf{i}) + 0\mathbf{j} + 8\left(\frac{4}{5}\right)(+\mathbf{k})$$
$$= \{-4.8\mathbf{i} + 6.4\mathbf{k}\}\text{kN}$$

$$\mathbf{F}_3 = 9\cos 45°\sin 30°(+\mathbf{i}) + 9\cos 45°\cos 30°(-\mathbf{j}) + 9\sin 45°(-\mathbf{k})$$
$$= \{3.182\mathbf{i} - 5.511\mathbf{j} - 6.364\mathbf{k}\}\text{ kN}$$

Resultant Force: By adding $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ vectorally, we obtain $\mathbf{F}_R$. Thus,

$$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3$$
$$= (-2.5\mathbf{i} + 4.330\mathbf{j} - 8.660\mathbf{k}) + (-4.8\mathbf{i} + 6.4\mathbf{k}) + (3.182\mathbf{i} - 5.511\mathbf{j} - 6.364\mathbf{k})$$
$$= \{-4.118\mathbf{i} - 1.181\mathbf{j} - 8.624\mathbf{k}\}\text{ kN}$$

The magnitude of $\mathbf{F}_R$ is

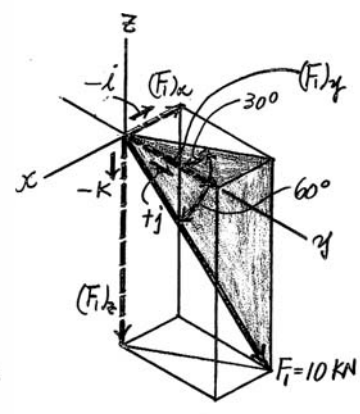
$$F_R = \sqrt{(F_R)_x^2 + (F_R)_y^2 + (F_R)_z^2}$$
$$= \sqrt{(-4.118)^2 + (-1.181)^2 + (-8.624)^2} = 9.630\text{ kN} = 9.63\text{ kN} \quad \textbf{Ans.}$$

The coordinate direction angles of $\mathbf{F}_R$ are

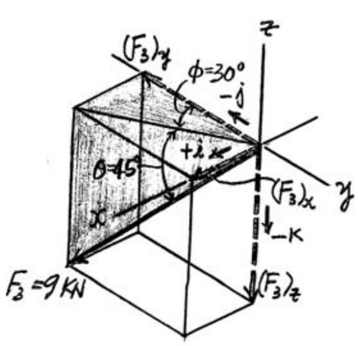
$$\alpha = \cos^{-1}\left[\frac{(F_R)_x}{F_R}\right] = \cos^{-1}\left(\frac{-4.118}{9.630}\right) = 115° \quad \textbf{Ans.}$$

$$\beta = \cos^{-1}\left[\frac{(F_R)_y}{F_R}\right] = \cos^{-1}\left(\frac{-1.181}{9.630}\right) = 97.0° \quad \textbf{Ans.}$$

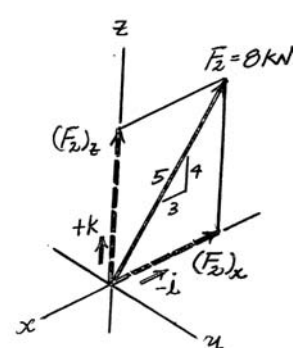
$$\gamma = \cos^{-1}\left[\frac{(F_R)_z}{F_R}\right] = \cos^{-1}\left(\frac{-8.624}{9.630}\right) = 154° \quad \textbf{Ans.}$$



(a)

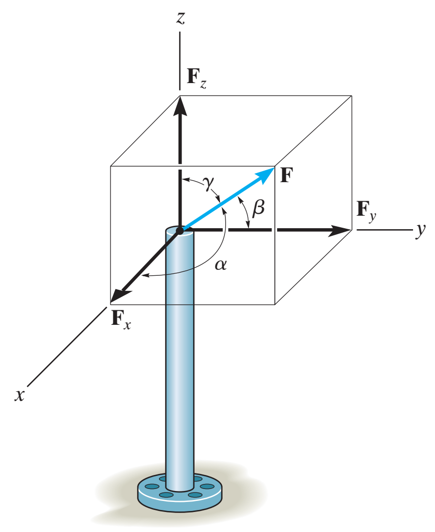


(c)



(b)

•2–81. The pole is subjected to the force **F**, which has components acting along the *x, y, z* axes as shown. If the magnitude of **F** is 3 kN, $\beta = 30°$, and $\gamma = 75°$, determine the magnitudes of its three components.



$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

$$\cos^2\alpha + \cos^2 30° + \cos^2 75° = 1$$

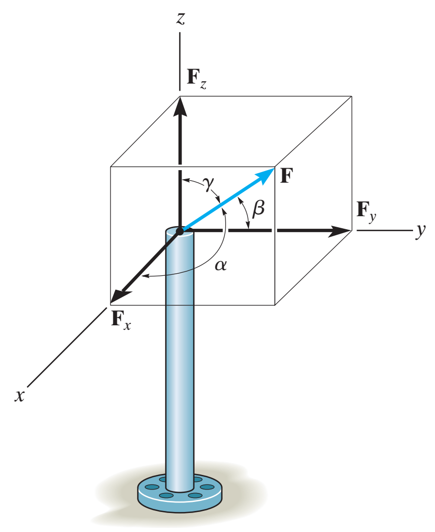
$$\alpha = 64.67°$$

$$F_x = 3\cos 64.67° = 1.28 \text{ kN} \qquad \textbf{Ans}$$

$$F_y = 3\cos 30° = 2.60 \text{ kN} \qquad \textbf{Ans}$$

$$F_z = 3\cos 75° = 0.776 \text{ kN} \qquad \textbf{Ans}$$

2–82. The pole is subjected to the force **F** which has components $F_x = 1.5$ kN and $F_z = 1.25$ kN. If $\beta = 75°$, determine the magnitudes of **F** and $\mathbf{F}_y$.



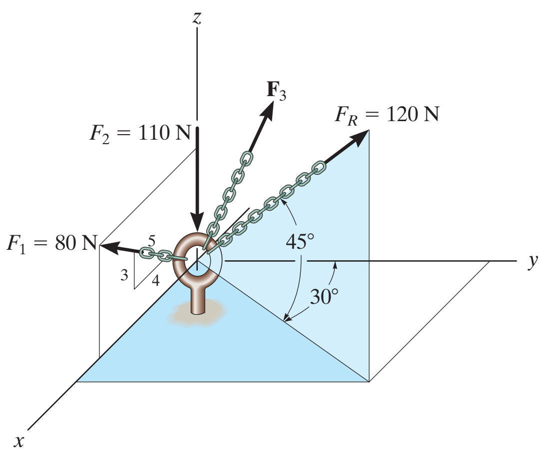
$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

$$\left(\frac{1.5}{F}\right)^2 + \cos^2 75° + \left(\frac{1.25}{F}\right)^2 = 1$$

$$F = 2.02 \text{ kN} \qquad \textbf{Ans}$$

$$F_y = 2.02\cos 75° = 0.523 \text{ kN} \qquad \textbf{Ans}$$

2–83. Three forces act on the ring. If the resultant force $\mathbf{F}_R$ has a magnitude and direction as shown, determine the magnitude and the coordinate direction angles of force $\mathbf{F}_3$.



Cartesian Vector Notation :

$$\mathbf{F}_R = 120\{\cos 45°\sin 30°\mathbf{i} + \cos 45°\cos 30°\mathbf{j} + \sin 45°\mathbf{k}\}\ \text{N}$$
$$= \{42.43\mathbf{i} + 73.48\mathbf{j} + 84.85\mathbf{k}\}\ \text{N}$$

$$\mathbf{F}_1 = 80\left\{\frac{4}{5}\mathbf{i} + \frac{3}{5}\mathbf{k}\right\}\text{N} = \{64.0\mathbf{i} + 48.0\mathbf{k}\}\ \text{N}$$

$$\mathbf{F}_2 = \{-110\mathbf{k}\}\ \text{N}$$

$$\mathbf{F}_3 = \{F_{3_x}\mathbf{i} + F_{3_y}\mathbf{j} + F_{3_z}\mathbf{k}\}\ \text{N}$$

Resultant Force :

$$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3$$
$$\{42.43\mathbf{i} + 73.48\mathbf{j} + 84.85\mathbf{k}\}$$
$$= \left\{\left(64.0 + F_{3_x}\right)\mathbf{i} + F_{3_y}\mathbf{j} + \left(48.0 - 110 + F_{3_z}\right)\mathbf{k}\right\}$$

Equating **i**, **j** and **k** components, we have

$$64.0 + F_{3_x} = 42.43 \qquad F_{3_x} = -21.57\ \text{N}$$
$$F_{3_y} = 73.48\ \text{N}$$
$$48.0 - 110 + F_{3_z} = 84.85 \qquad F_{3_z} = 146.85\ \text{N}$$

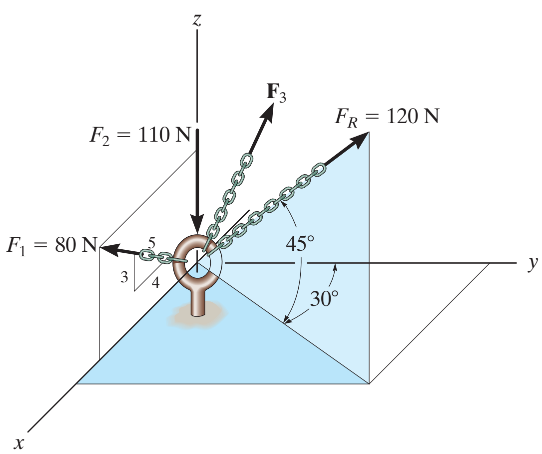
The magnitude of force $\mathbf{F}_3$ is

$$F_3 = \sqrt{F_{3_x}^2 + F_{3_y}^2 + F_{3_z}^2}$$
$$= \sqrt{(-21.57)^2 + 73.48^2 + 146.85^2}$$
$$= 165.62\ \text{N} = 166\ \text{N} \qquad \textbf{Ans}$$

The coordinate direction angles for $\mathbf{F}_3$ are

$$\cos\alpha = \frac{F_{3_x}}{F_3} = \frac{-21.57}{165.62} \qquad \alpha = 97.5° \qquad \textbf{Ans}$$
$$\cos\beta = \frac{F_{3_y}}{F_3} = \frac{73.48}{165.62} \qquad \beta = 63.7° \qquad \textbf{Ans}$$
$$\cos\gamma = \frac{F_{3_z}}{F_3} = \frac{146.85}{165.62} \qquad \gamma = 27.5° \qquad \textbf{Ans}$$

***2–84.** Determine the coordinate direction angles of $\mathbf{F}_1$ and $\mathbf{F}_R$.



Unit Vector of $\mathbf{F}_1$ and $\mathbf{F}_R$:

$$\mathbf{u}_{F_1} = \frac{4}{5}\mathbf{i} + \frac{3}{5}\mathbf{k} = 0.8\mathbf{i} + 0.6\mathbf{k}$$

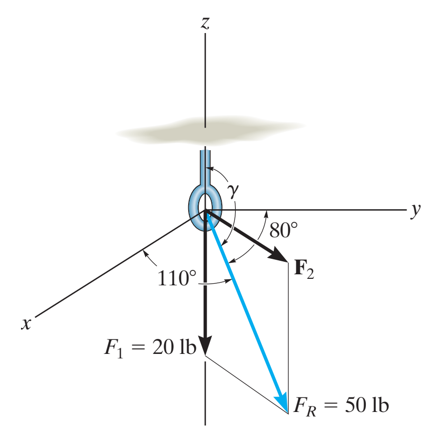
$$\mathbf{u}_R = \cos 45°\sin 30°\mathbf{i} + \cos 45°\cos 30°\mathbf{j} + \sin 45°\mathbf{k}$$
$$= 0.3536\mathbf{i} + 0.6124\mathbf{j} + 0.7071\mathbf{k}$$

Thus, the coordinate direction angles $\mathbf{F}_1$ and $\mathbf{F}_R$ are

$$\cos\alpha_{F_1} = 0.8 \qquad \alpha_{F_1} = 36.9° \qquad \textbf{Ans}$$
$$\cos\beta_{F_1} = 0 \qquad \beta_{F_1} = 90.0° \qquad \textbf{Ans}$$
$$\cos\gamma_{F_1} = 0.6 \qquad \gamma_{F_1} = 53.1° \qquad \textbf{Ans}$$

$$\cos\alpha_R = 0.3536 \qquad \alpha_R = 69.3° \qquad \textbf{Ans}$$
$$\cos\beta_R = 0.6124 \qquad \beta_R = 52.2° \qquad \textbf{Ans}$$
$$\cos\gamma_R = 0.7071 \qquad \gamma_R = 45.0° \qquad \textbf{Ans}$$

•**2–85.** Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on the bolt. If the resultant force $\mathbf{F}_R$ has a magnitude of 50 lb and coordinate direction angles $\alpha = 110°$ and $\beta = 80°$, as shown, determine the magnitude of $\mathbf{F}_2$ and its coordinate direction angles.



$$(1)^2 = \cos^2 110° + \cos^2 80° + \cos^2\gamma$$

$$\gamma = 157.44°$$

$$F_R = F_1 + F_2$$

$$50\cos 110° = (F_2)_x$$

$$50\cos 80° = (F_2)_y$$

$$50\cos 157.44° = (F_2)_z - 20$$

$$(F_2)_x = -17.10$$

$$(F_2)_y = 8.68$$

$$(F_2)_z = -26.17$$

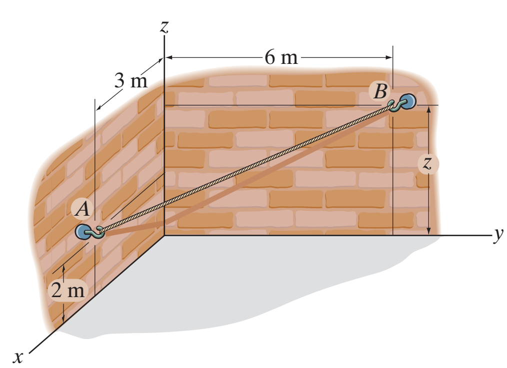
$$F_2 = \sqrt{(-17.10)^2 + (8.68)^2 + (-26.17)^2} = 32.4 \text{ lb} \qquad \textbf{Ans}$$

$$\alpha_2 = \cos^{-1}\left(\frac{-17.10}{32.4}\right) = 122° \qquad \textbf{Ans}$$

$$\beta_2 = \cos^{-1}\left(\frac{8.68}{32.4}\right) = 74.5° \qquad \textbf{Ans}$$

$$\gamma_2 = \cos^{-1}\left(\frac{-26.17}{32.4}\right) = 144° \qquad \textbf{Ans}$$

2–86. Determine the position vector $\mathbf{r}$ directed from point A to point B and the length of cord AB. Take $z = 4$ m.



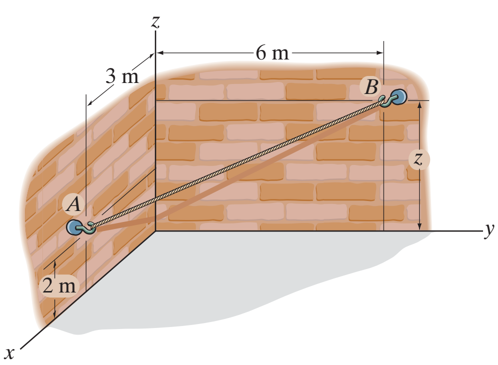
Position Vector: The coordinates for points A and B are $A(3, 0, 2)$ m and $B(0, 6, 4)$ m, respectively. Thus,

$$\mathbf{r}_{AB} = (0-3)\mathbf{i} + (6-0)\mathbf{j} + (4-2)\mathbf{k}$$
$$= \{-3\mathbf{i} + 6\mathbf{j} + 2\mathbf{k}\} \text{ m} \qquad \textbf{Ans.}$$

The length of cord AB is

$$r_{AB} = \sqrt{(-3)^2 + 6^2 + 2^2} = 7 \text{ m} \qquad \textbf{Ans.}$$

2–87. If the cord AB is 7.5 m long, determine the coordinate position $+z$ of point B



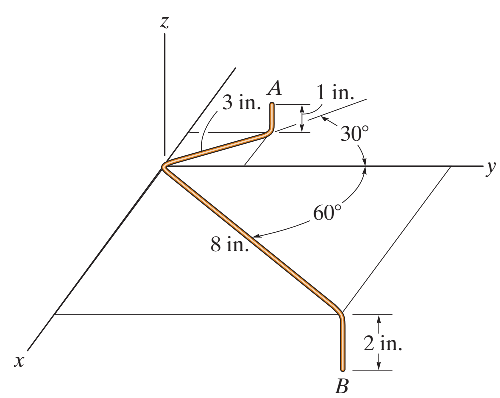
Position Vector: The coordinates for points A and B are $A(3, 0, 2)$ m and $B(0, 6, z)$ m, respectively. Thus,

$$\mathbf{r}_{AB} = (0-3)\mathbf{i} + (6-0)\mathbf{j} + (z-2)\mathbf{k}$$
$$= \{-3\mathbf{i} + 6\mathbf{j} + (z-2)\mathbf{k}\} \text{ m}$$

Since the length of cord is equal to the magnitude of $\mathbf{r}_{AB}$, then

$$r_{AB} = 7.5 = \sqrt{(-3)^2 + 6^2 + (z-2)^2}$$
$$56.25 = 45 + (z-2)^2$$
$$z - 2 = \pm 3.354$$
$$z = 5.35 \text{ m} \qquad \textbf{Ans.}$$

***2–88.** Determine the distance between the end points A and B on the wire by first formulating a position vector from A to B and then determining its magnitude.

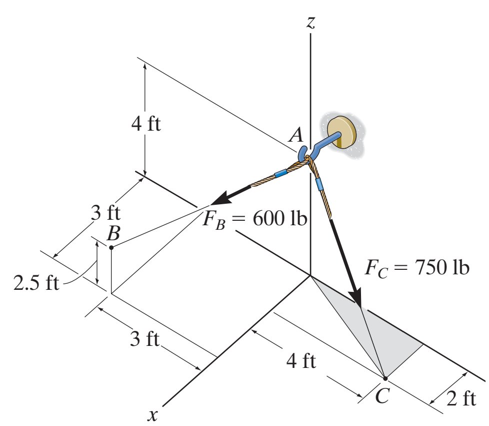


$$\mathbf{r}_{AB} = (8\sin 60° - (-3\sin 30°))\,\mathbf{i} + (8\cos 60° - 3\cos 30°)\,\mathbf{j} + (-2 - 1)\,\mathbf{k}$$

$$\mathbf{r}_{AB} = \{8.428\,\mathbf{i} + 1.402\,\mathbf{j} - 3\,\mathbf{k}\} \text{ in.}$$

$$r_{AB} = \sqrt{(8.428)^2 + (1.402)^2 + (-3)^2} = 9.06 \text{ in.} \qquad \textbf{Ans}$$

•2–89. Determine the magnitude and coordinate direction angles of the resultant force acting at A.



Unit Vectors: The coordinate points A, B, and C are shown in Fig. *a*. Thus,

$$\mathbf{u}_B = \frac{\mathbf{r}_B}{r_B} = \frac{(3-0)\mathbf{i}+(-3-0)\mathbf{j}+(2.5-4)\mathbf{k}}{\sqrt{(3-0)^2+(-3-0)^2+(2.5-4)^2}} = \frac{2}{3}\mathbf{i}-\frac{2}{3}\mathbf{j}-\frac{1}{3}\mathbf{k}$$

$$\mathbf{u}_C = \frac{\mathbf{r}_C}{r_C} = \frac{(2-0)\mathbf{i}+(4-0)\mathbf{j}+(0-4)\mathbf{k}}{\sqrt{(2-0)^2+(4-0)^2+(0-4)^2}} = \frac{1}{3}\mathbf{i}+\frac{2}{3}\mathbf{j}-\frac{2}{3}\mathbf{k}$$

Force Vectors: Multiplying the magnitude of the force with its unit vector, we have

$$\mathbf{F}_B = F_B\mathbf{u}_B = 600\left(\frac{2}{3}\mathbf{i}-\frac{2}{3}\mathbf{j}-\frac{1}{3}\mathbf{k}\right) = \{400\mathbf{i}-400\mathbf{j}-200\mathbf{k}\}\text{ lb} \qquad \textbf{Ans.}$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = 750\left(\frac{1}{3}\mathbf{i}+\frac{2}{3}\mathbf{j}-\frac{2}{3}\mathbf{k}\right) = \{250\mathbf{i}+500\mathbf{j}-500\mathbf{k}\}\text{ lb} \qquad \textbf{Ans.}$$

$$\mathbf{F}_R = \mathbf{F}_B+\mathbf{F}_C = 400\mathbf{i}-400\mathbf{j}-200\mathbf{k}+250\mathbf{i}+500\mathbf{j}-500\mathbf{k}$$

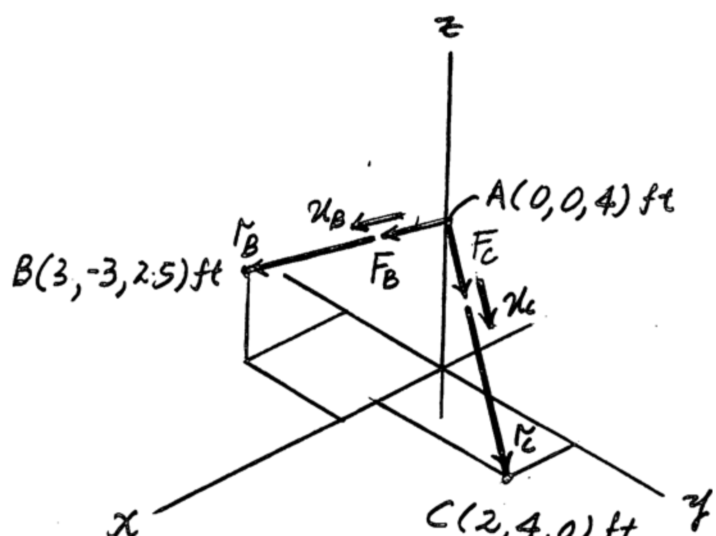
$$\mathbf{F}_R = \{650\mathbf{i}+100\mathbf{j}-700\mathbf{k}\}\text{ lb}$$

$$F_R = \sqrt{650^2+100^2+(-700)^2} = 960\text{ lb} \qquad \textbf{Ans.}$$

$$\alpha = \cos^{-1}\left[\frac{(F_R)_x}{F_R}\right] = \cos^{-1}\left(\frac{650}{960}\right) = 47.4° \qquad \textbf{Ans.}$$

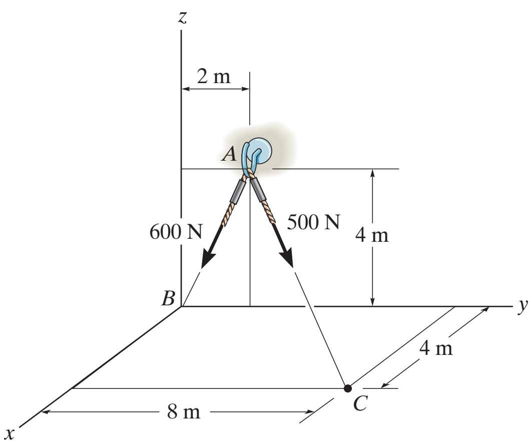
$$\beta = \cos^{-1}\left[\frac{(F_R)_y}{F_R}\right] = \cos^{-1}\left(\frac{100}{960}\right) = 84.0° \qquad \textbf{Ans.}$$

$$\gamma = \cos^{-1}\left[\frac{(F_R)_z}{F_R}\right] = \cos^{-1}\left(\frac{-700}{960}\right) = 137° \qquad \textbf{Ans.}$$



(a)

2–90. Determine the magnitude and coordinate direction angles of the resultant force.



$\mathbf{r}_{AB} = \{-2\,\mathbf{j} - 4\,\mathbf{k}\}\text{m}; \quad r_{AB} = 4.472\text{ m}$

$\mathbf{u}_{AB} = \left(\frac{\mathbf{r}_{AB}}{r_{AB}}\right) = -0.447\,\mathbf{j} - 0.894\,\mathbf{k}$

$\mathbf{F}_{AB} = 600\,\mathbf{u}_{AB} = \{-268.33\,\mathbf{j} - 536.66\,\mathbf{k}\}\text{N}$

$\mathbf{r}_{AC} = \{4\,\mathbf{i} + 6\,\mathbf{j} - 4\,\mathbf{k}\}\text{m}; \quad r_{AC} = 8.246\text{ m}$

$\mathbf{u}_{AC} = \left(\frac{\mathbf{r}_{AC}}{r_{AC}}\right) = 0.485\,\mathbf{i} + 0.728\,\mathbf{j} - 0.485\,\mathbf{k}$

$\mathbf{F}_{AC} = 500\,\mathbf{u}_{AC} = \{242.54\,\mathbf{i} + 363.80\,\mathbf{j} - 242.54\,\mathbf{k}\}\text{N}$

$\mathbf{F}_R = \mathbf{F}_{AB} + \mathbf{F}_{AC}$

$\mathbf{F}_R = \{242.54\,\mathbf{i} + 95.47\,\mathbf{j} - 779.20\,\mathbf{k}\}$

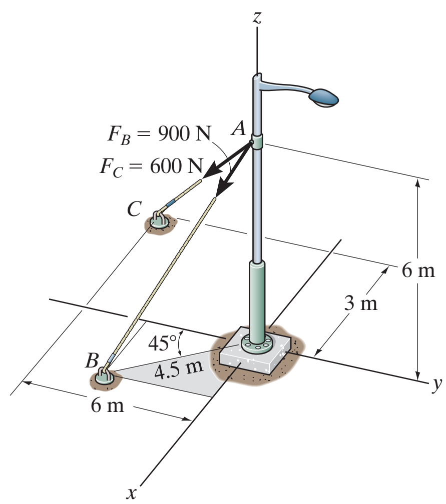
$F_R = \sqrt{(242.54)^2 + (95.47)^2 + (-779.20)^2} = 821.64 = 822\text{ N}$ **Ans**

$\alpha = \cos^{-1}\left(\frac{242.54}{821.64}\right) = 72.8^\circ$ **Ans**

$\beta = \cos^{-1}\left(\frac{95.47}{821.64}\right) = 83.3^\circ$ **Ans**

$\gamma = \cos^{-1}\left(\frac{-779.20}{821.64}\right) = 162^\circ$ **Ans**

2–91. Determine the magnitude and coordinate direction angles of the resultant force acting at A.



Force Vectors: The unit vectors $\mathbf{u}_B$ and $\mathbf{u}_C$ of $\mathbf{F}_B$ and $\mathbf{F}_C$ must be determined first. From Fig. *a*

$$\mathbf{u}_B = \frac{\mathbf{r}_B}{r_B} = \frac{(4.5\sin 45^\circ - 0)\mathbf{i} + (-4.5\cos 45^\circ - 0)\mathbf{j} + (0-6)\mathbf{k}}{\sqrt{(4.5\sin 45^\circ - 0)^2 + (-4.5\cos 45^\circ - 0)^2 + (0-6)^2}}$$
$$= 0.4243\mathbf{i} - 0.4243\mathbf{j} - 0.8\mathbf{k}$$

$$\mathbf{u}_C = \frac{\mathbf{r}_C}{r_C} = \frac{(-3-0)\mathbf{i} + (-6-0)\mathbf{j} + (0-6)\mathbf{k}}{\sqrt{(-3-0)^2 + (-6-0)^2 + (0-6)^2}}$$
$$= -\frac{1}{3}\mathbf{i} - \frac{2}{3}\mathbf{j} - \frac{2}{3}\mathbf{k}$$

Thus, the force vectors $\mathbf{F}_B$ and $\mathbf{F}_C$ are given by

$$\mathbf{F}_B = F_B\mathbf{u}_B = 900(0.4243\mathbf{i} - 0.4243\mathbf{j} - 0.8\mathbf{k}) = \{381.84\mathbf{i} - 381.84\mathbf{j} - 720\mathbf{k}\}\text{N}$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = 600\left(-\frac{1}{3}\mathbf{i} - \frac{2}{3}\mathbf{j} - \frac{2}{3}\mathbf{k}\right) = \{-200\mathbf{i} - 400\mathbf{j} - 400\mathbf{k}\}\text{N}$$

Resultant Force:

$$\mathbf{F}_R = \mathbf{F}_B + \mathbf{F}_C = (381.84\mathbf{i} - 381.84\mathbf{j} - 720\mathbf{k}) + (-200\mathbf{i} - 400\mathbf{j} - 400\mathbf{k})$$
$$= \{181.84\mathbf{i} - 781.84\mathbf{j} - 1120\mathbf{k}\}\text{ N}$$

The magnitude of $\mathbf{F}_R$ is

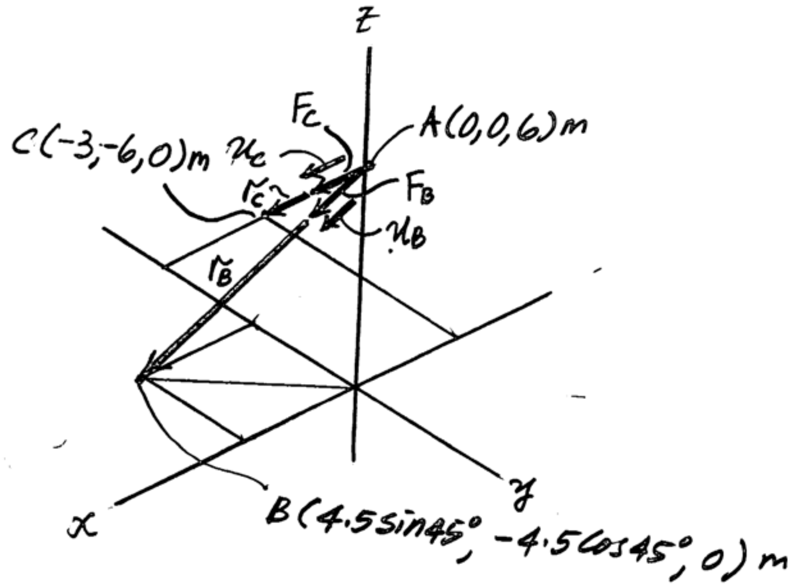
$$F_R = \sqrt{(F_R)_x^2 + (F_R)_y^2 + (F_R)_z^2}$$
$$= \sqrt{(181.84)^2 + (-781.84)^2 + (-1120)^2} = 1377.95\text{ N} = 1.38\text{ kN} \qquad \textbf{Ans.}$$

The coordinate direction angles of $\mathbf{F}_R$ are

$$\alpha = \cos^{-1}\left[\frac{(F_R)_x}{F_R}\right] = \cos^{-1}\left(\frac{181.84}{1377.95}\right) = 82.4^\circ \qquad \textbf{Ans.}$$

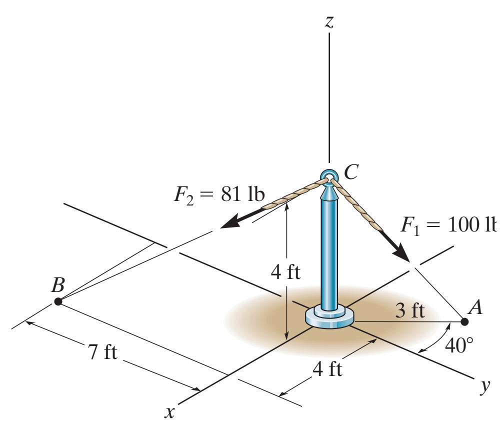
$$\beta = \cos^{-1}\left[\frac{(F_R)_y}{F_R}\right] = \cos^{-1}\left(\frac{-781.84}{1377.95}\right) = 125^\circ \qquad \textbf{Ans.}$$

$$\gamma = \cos^{-1}\left[\frac{(F_R)_z}{F_R}\right] = \cos^{-1}\left(\frac{-1120}{1377.95}\right) = 144^\circ \qquad \textbf{Ans.}$$



(a)

***2–92.** Determine the magnitude and coordinate direction angles of the resultant force.



$$\mathbf{F}_1 = -100\left(\frac{3}{5}\right)\sin 40°\,\mathbf{i} + 100\left(\frac{3}{5}\right)\cos 40°\,\mathbf{j} - 100\left(\frac{4}{5}\right)\mathbf{k}$$

$$= \{-38.567\,\mathbf{i} + 45.963\,\mathbf{j} - 80\,\mathbf{k}\}\text{ lb}$$

$$\mathbf{F}_2 = 81\text{ lb}\left(\frac{4}{9}\,\mathbf{i} - \frac{7}{9}\,\mathbf{j} - \frac{4}{9}\,\mathbf{k}\right)$$

$$= \{36\,\mathbf{i} - 63\,\mathbf{j} - 36\,\mathbf{k}\}\text{lb}$$

$$\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2 = \{-2.567\,\mathbf{i} - 17.04\,\mathbf{j} - 116.0\,\mathbf{k}\}\text{ lb}$$

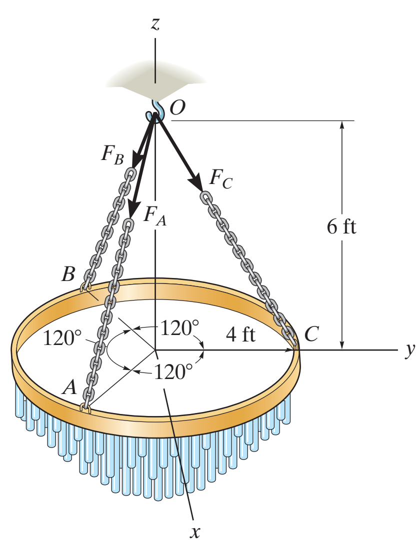
$$F_R = \sqrt{(-2.567)^2 + (-17.04)^2 + (-116.0)^2} = 117.27\text{ lb} = 117\text{ lb} \qquad \textbf{Ans}$$

$$\alpha = \cos^{-1}\left(\frac{-2.567}{117.27}\right) = 91.3° \qquad \textbf{Ans}$$

$$\beta = \cos^{-1}\left(\frac{-17.04}{117.27}\right) = 98.4° \qquad \textbf{Ans}$$

$$\gamma = \cos^{-1}\left(\frac{-116.0}{117.27}\right) = 172° \qquad \textbf{Ans}$$

•2–93. The chandelier is supported by three chains which are concurrent at point O. If the force in each chain has a magnitude of 60 lb, express each force as a Cartesian vector and determine the magnitude and coordinate direction angles of the resultant force.



$$\mathbf{F}_A = 60\,\frac{(4\cos 30°\,\mathbf{i} - 4\sin 30°\,\mathbf{j} - 6\,\mathbf{k})}{\sqrt{(4\cos 30°)^2 + (-4\sin 30°)^2 + (-6)^2}}$$

$$= \{28.8\,\mathbf{i} - 16.6\,\mathbf{j} - 49.9\,\mathbf{k}\}\text{ lb} \qquad \textbf{Ans}$$

$$\mathbf{F}_B = 60\,\frac{(-4\cos 30°\,\mathbf{i} - 4\sin 30°\,\mathbf{j} - 6\,\mathbf{k})}{\sqrt{(-4\cos 30°)^2 + (-4\sin 30°)^2 + (-6)^2}}$$

$$= \{-28.8\,\mathbf{i} - 16.6\,\mathbf{j} - 49.9\,\mathbf{k}\}\text{ lb} \qquad \textbf{Ans}$$

$$\mathbf{F}_C = 60\,\frac{(4\,\mathbf{j} - 6\,\mathbf{k})}{\sqrt{(4)^2 + (-6)^2}}$$

$$= \{33.3\,\mathbf{j} - 49.9\,\mathbf{k}\}\text{ lb} \qquad \textbf{Ans}$$

$$\mathbf{F}_R = \mathbf{F}_A + \mathbf{F}_B + \mathbf{F}_C = \{-149.8\,\mathbf{k}\}\text{ lb}$$

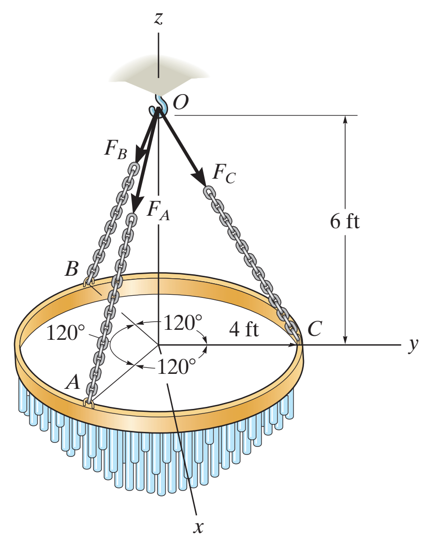
$$F_R = 150\text{ lb} \qquad \textbf{Ans}$$

$$\alpha = 90° \qquad \textbf{Ans}$$

$$\beta = 90° \qquad \textbf{Ans}$$

$$\gamma = 180° \qquad \textbf{Ans}$$

2–94. The chandelier is supported by three chains which are concurrent at point O. If the resultant force at O has a magnitude of 130 lb and is directed along the negative z axis, determine the force in each chain.



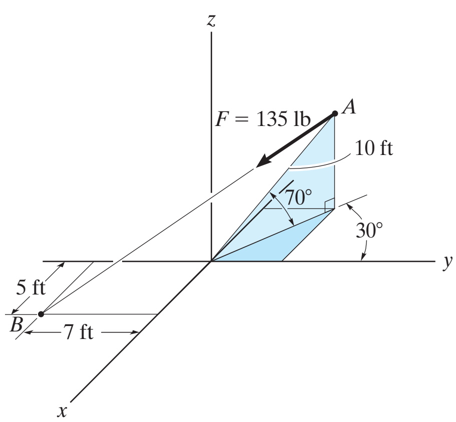
$$\mathbf{F}_C = F\frac{(4\,\mathbf{j} - 6\,\mathbf{k})}{\sqrt{4^2 + (-6)^2}} = 0.5547\,F\,\mathbf{j} - 0.8321\,F\,\mathbf{k}$$

$$\mathbf{F}_A = \mathbf{F}_B = \mathbf{F}_C$$

$F_{R_z} = \Sigma F_z;\quad 130 = 3(0.8321\,F)$

$F = 52.1$ lb **Ans**

2–95. Express force **F** as a Cartesian vector; then determine its coordinate direction angles.



Unit Vector : The coordinates of point A are

$$A(-10\cos 70°\sin 30°,\ 10\cos 70°\cos 30°,\ 10\sin 70°)\ \text{ft}$$
$$= A(-1.710,\ 2.962,\ 9.397)\ \text{ft}$$

Then

$$\mathbf{r}_{AB} = \{[5-(-1.710)]\mathbf{i} + (-7-2.962)\mathbf{j} + (0-9.397)\mathbf{k}\}\ \text{ft}$$
$$= \{6.710\mathbf{i} - 9.962\mathbf{j} - 9.397\mathbf{k}\}\ \text{ft}$$
$$r_{AB} = \sqrt{6.710^2 + (-9.962)^2 + (-9.397)^2} = 15.250\ \text{ft}$$

$$\mathbf{u}_{AB} = \frac{\mathbf{r}_{AB}}{r_{AB}} = \frac{6.710\mathbf{i} - 9.962\mathbf{j} - 9.397\mathbf{k}}{15.250}$$
$$= 0.4400\mathbf{i} - 0.6532\mathbf{j} - 0.6162\mathbf{k}$$

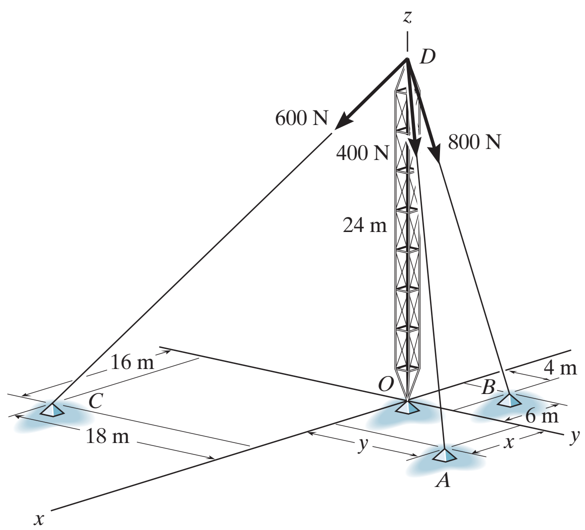
Force Vector :

$$\mathbf{F} = F\mathbf{u}_{AB} = 135\{0.4400\mathbf{i} - 0.6532\mathbf{j} - 0.6162\mathbf{k}\}\ \text{lb}$$
$$= \{59.4\mathbf{i} - 88.2\mathbf{j} - 83.2\mathbf{k}\}\ \text{lb} \qquad \textbf{Ans}$$

Coordinate Direction Angles : From the unit vector $\mathbf{u}_{AB}$ obtained above, we have

$\cos\alpha = 0.4400$ $\quad\alpha = 63.9°$ **Ans**
$\cos\beta = -0.6532$ $\quad\beta = 131°$ **Ans**
$\cos\gamma = -0.6162$ $\quad\gamma = 128°$ **Ans**

***2–96.** The tower is held in place by three cables. If the force of each cable acting on the tower is shown, determine the magnitude and coordinate direction angles α, β, γ of the resultant force. Take $x = 20$ m, $y = 15$ m.



$$\mathbf{F}_{DA} = 400\left(\frac{20}{34.66}\mathbf{i} + \frac{15}{34.66}\mathbf{j} - \frac{24}{34.66}\mathbf{k}\right) \text{ N}$$

$$\mathbf{F}_{DB} = 800\left(\frac{-6}{25.06}\mathbf{i} + \frac{4}{25.06}\mathbf{j} - \frac{24}{25.06}\mathbf{k}\right) \text{ N}$$

$$\mathbf{F}_{DC} = 600\left(\frac{16}{34}\mathbf{i} - \frac{18}{34}\mathbf{j} - \frac{24}{34}\mathbf{k}\right) \text{ N}$$

$$\mathbf{F}_R = \mathbf{F}_{DA} + \mathbf{F}_{DB} + \mathbf{F}_{DC}$$

$$= \{321.66\mathbf{i} - 16.82\mathbf{j} - 1466.71\mathbf{k}\} \text{ N}$$

$$F_R = \sqrt{(321.66)^2 + (-16.82)^2 + (-1466.71)^2}$$

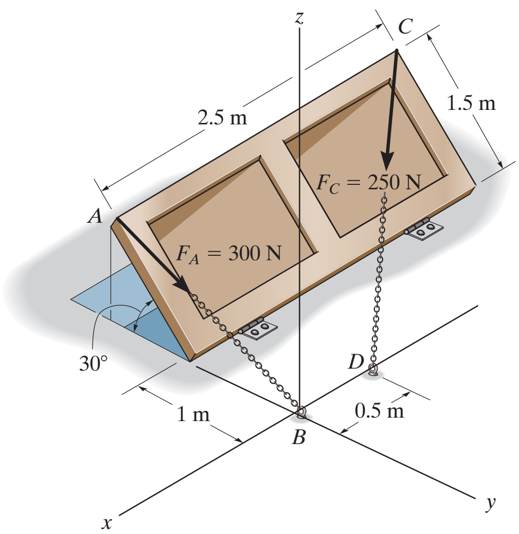
$$= 1501.66 \text{ N} = 1.50 \text{ kN} \qquad \textbf{Ans}$$

$$\alpha = \cos^{-1}\left(\frac{321.66}{1501.66}\right) = 77.6^\circ \qquad \textbf{Ans}$$

$$\beta = \cos^{-1}\left(\frac{-16.82}{1501.66}\right) = 90.6^\circ \qquad \textbf{Ans}$$

$$\gamma = \cos^{-1}\left(\frac{-1466.71}{1501.66}\right) = 168^\circ \qquad \textbf{Ans}$$

•2–97. The door is held opened by means of two chains. If the tension in AB and CD is $F_A = 300$ N and $F_C = 250$ N, respectively, express each of these forces in Cartesian vector form.



Unit Vector : First determine the position vector $\mathbf{r}_{AB}$ and $\mathbf{r}_{CD}$. The coordinates of points A and C are

$$A[0,\ -(1+1.5\cos 30°),\ 1.5\sin 30°]\ \text{m} = A(0,\ -2.299,\ 0.750)\ \text{m}$$
$$C[-2.50,\ -(1+1.5\cos 30°),\ 1.5\sin 300°]\ \text{m} = C(-2.50,\ -2.299,\ 0.750)\ \text{m}$$

Then

$$\mathbf{r}_{AB} = \{(0-0)\mathbf{i} + [0-(-2.299)]\mathbf{j} + (0-0.750)\mathbf{k}\}\ \text{m} = \{2.299\mathbf{j} - 0.750\mathbf{k}\}\ \text{m}$$
$$r_{AB} = \sqrt{2.299^2 + (-0.750)^2} = 2.418\ \text{m}$$
$$\mathbf{u}_{AB} = \frac{\mathbf{r}_{AB}}{r_{AB}} = \frac{2.299\mathbf{j} - 0.750\mathbf{k}}{2.418} = 0.9507\mathbf{j} - 0.3101\mathbf{k}$$

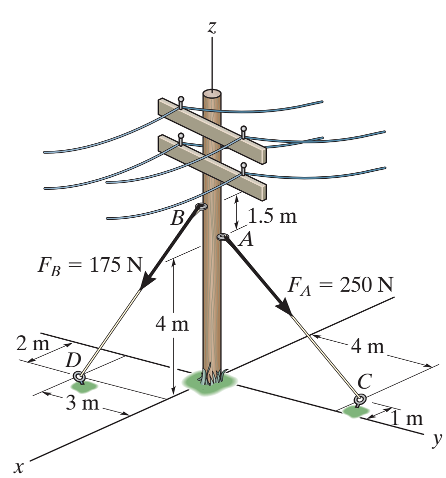
$$\mathbf{r}_{CD} = \{[-0.5-(-2.5)]\mathbf{i} + [0-(-2.299)]\mathbf{j} + (0-0.750)\mathbf{k}\}\ \text{m} = \{2.00\mathbf{i} + 2.299\mathbf{j} - 0.750\mathbf{k}\}\ \text{m}$$
$$r_{CD} = \sqrt{2.00^2 + 2.299^2 + (-0.750)^2} = 3.138\ \text{m}$$
$$\mathbf{u}_{CD} = \frac{\mathbf{r}_{CD}}{r_{CD}} = \frac{2.00\mathbf{i} + 2.299\mathbf{j} - 0.750\mathbf{k}}{3.138} = 0.6373\mathbf{i} + 0.7326\mathbf{j} - 0.2390\mathbf{k}$$

Force Vector :

$$\mathbf{F}_A = F_A\mathbf{u}_{AB} = 300\{0.9507\mathbf{j} - 0.3101\mathbf{k}\}\ \text{N} = \{285.21\mathbf{j} - 93.04\mathbf{k}\}\ \text{N} = \{285\mathbf{j} - 93.0\mathbf{k}\}\ \text{N}$$ **Ans**

$$\mathbf{F}_C = F_C\mathbf{u}_{CD} = 250\{0.6373\mathbf{i} + 0.7326\mathbf{j} - 0.2390\mathbf{k}\}\ \text{N} = \{159.33\mathbf{i} + 183.15\mathbf{j} - 59.75\mathbf{k}\}\ \text{N} = \{159\mathbf{i} + 183\mathbf{j} - 59.7\mathbf{k}\}\ \text{N}$$ **Ans**

2–98. The guy wires are used to support the telephone pole. Represent the force in each wire in Cartesian vector form. Neglect the diameter of the pole.



Unit Vector :

$$\mathbf{r}_{AC} = \{(-1-0)\mathbf{i} + (4-0)\mathbf{j} + (0-4)\mathbf{k}\}\ \text{m} = \{-1\mathbf{i} + 4\mathbf{j} - 4\mathbf{k}\}\ \text{m}$$
$$r_{AC} = \sqrt{(-1)^2 + 4^2 + (-4)^2} = 5.745\ \text{m}$$
$$\mathbf{u}_{AC} = \frac{\mathbf{r}_{AC}}{r_{AC}} = \frac{-1\mathbf{i} + 4\mathbf{j} - 4\mathbf{k}}{5.745} = -0.1741\mathbf{i} + 0.6963\mathbf{j} - 0.6963\mathbf{k}$$

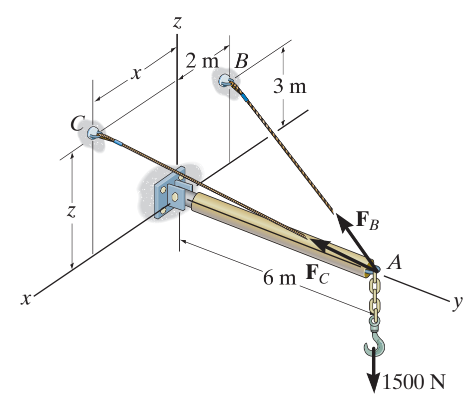
$$\mathbf{r}_{BD} = \{(2-0)\mathbf{i} + (-3-0)\mathbf{j} + (0-5.5)\mathbf{k}\}\ \text{m} = \{2\mathbf{i} - 3\mathbf{j} - 5.5\mathbf{k}\}\ \text{m}$$
$$r_{BD} = \sqrt{2^2 + (-3)^2 + (-5.5)^2} = 6.576\ \text{m}$$
$$\mathbf{u}_{BD} = \frac{\mathbf{r}_{BD}}{r_{BD}} = \frac{2\mathbf{i} - 3\mathbf{j} - 5.5\mathbf{k}}{6.576} = 0.3041\mathbf{i} - 0.4562\mathbf{j} - 0.8363\mathbf{k}$$

Force Vector :

$$\mathbf{F}_A = F_A\mathbf{u}_{AC} = 250\{-0.1741\mathbf{i} + 0.6963\mathbf{j} - 0.6963\mathbf{k}\}\ \text{N} = \{-43.52\mathbf{i} + 174.08\mathbf{j} - 174.08\mathbf{k}\}\ \text{N} = \{-43.5\mathbf{i} + 174\mathbf{j} - 174\mathbf{k}\}\ \text{N}$$ **Ans**

$$\mathbf{F}_B = F_B\mathbf{u}_{BD} = 175\{0.3041\mathbf{i} - 0.4562\mathbf{j} - 0.8363\mathbf{k}\}\ \text{N} = \{53.22\mathbf{i} - 79.83\mathbf{j} - 146.36\mathbf{k}\}\ \text{N} = \{53.2\mathbf{i} - 79.8\mathbf{j} - 146\mathbf{k}\}\ \text{N}$$ **Ans**

2–99. Two cables are used to secure the overhang boom in position and support the 1500-N load. If the resultant force is directed along the boom from point A towards O, determine the magnitudes of the resultant force and forces $\mathbf{F}_B$ and $\mathbf{F}_C$. Set $x = 3$ m and $z = 2$ m.



Force Vectors: The unit vectors $\mathbf{u}_B$ and $\mathbf{u}_C$ must be determined first. From Fig. *a*,

$$\mathbf{u}_B = \frac{\mathbf{r}_B}{r_B} = \frac{(-2-0)\mathbf{i}+(0-6)\mathbf{j}+(3-0)\mathbf{k}}{\sqrt{(-2-0)^2+(0-6)^2+(3-0)^2}} = -\frac{2}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{3}{7}\mathbf{k}$$

$$\mathbf{u}_C = \frac{\mathbf{r}_C}{r_C} = \frac{(3-0)\mathbf{i}+(0-6)\mathbf{j}+(2-0)\mathbf{k}}{\sqrt{(3-0)^2+(0-6)^2+(2-0)^2}} = \frac{3}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{2}{7}\mathbf{k}$$

Thus, the force vectors $\mathbf{F}_B$ and $\mathbf{F}_C$ are given by

$$\mathbf{F}_B = F_B\mathbf{u}_B = -\frac{2}{7}F_B\mathbf{i}-\frac{6}{7}F_B\mathbf{j}+\frac{3}{7}F_B\mathbf{k}$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = \frac{3}{7}F_C\mathbf{i}-\frac{6}{7}F_C\mathbf{j}+\frac{2}{7}F_C\mathbf{k}$$

Since the resultant force $\mathbf{F}_R$ is directed along the negative y axis, and the load $\mathbf{W}$ is directed along the z axis, these two forces can be written as

$$\mathbf{F}_R = -F_R\mathbf{j} \qquad \text{and} \qquad \mathbf{W} = [-1500\mathbf{k}]\ \text{N}$$

Resultant Force: The vector addition of $\mathbf{F}_B$, $\mathbf{F}_C$, and $\mathbf{W}$ is equal to $\mathbf{F}_R$. Thus,

$$\mathbf{F}_R = \mathbf{F}_B + \mathbf{F}_C + \mathbf{W}$$

$$-F_R\mathbf{j} = \left(-\frac{2}{7}F_B\mathbf{i}-\frac{6}{7}F_B\mathbf{j}+\frac{3}{7}F_B\mathbf{k}\right)+\left(\frac{3}{7}F_C\mathbf{i}-\frac{6}{7}F_C\mathbf{j}+\frac{2}{7}F_C\mathbf{k}\right)+(-1500\mathbf{k})$$

$$-F_R\mathbf{j} = \left(-\frac{2}{7}F_B+\frac{3}{7}F_C\right)\mathbf{i}+\left(-\frac{6}{7}F_B-\frac{6}{7}F_C\right)\mathbf{j}+\left(\frac{3}{7}F_B+\frac{2}{7}F_C-1500\right)\mathbf{k}$$

Equating the $\mathbf{i}$, $\mathbf{j}$, and $\mathbf{k}$ components,

$$0 = -\frac{2}{7}F_B+\frac{3}{7}F_C \qquad (1)$$

$$-F_R = -\frac{6}{7}F_B-\frac{6}{7}F_C \qquad (2)$$

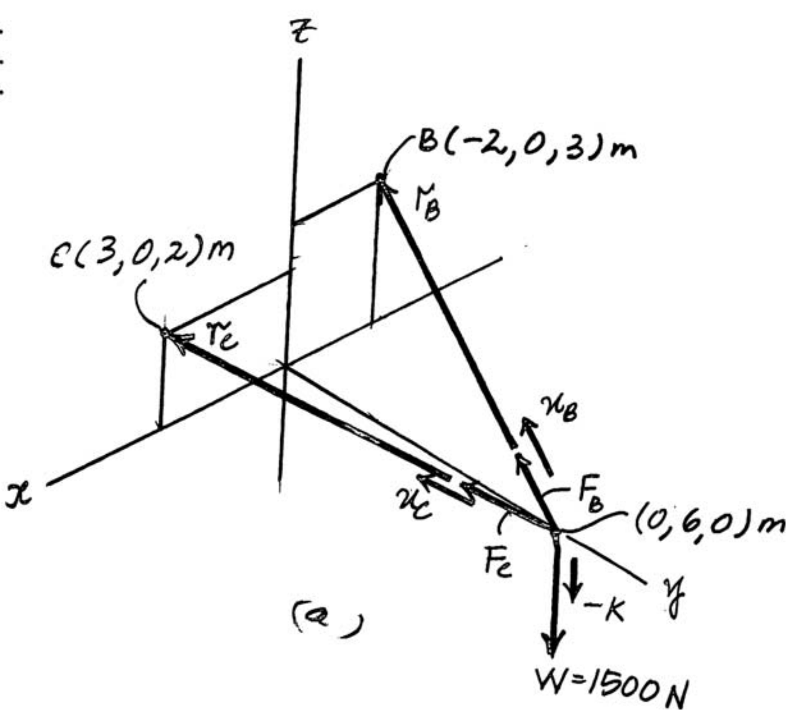
$$0 = \frac{3}{7}F_B+\frac{2}{7}F_C-1500 \qquad (3)$$

Solving Eqs. (1), (2), and (3) yields

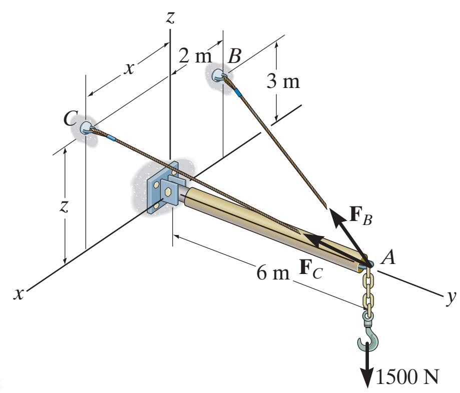
$F_C = 1615.38\text{ N} = 1.62\text{ kN}$ **Ans.**

$F_B = 2423.08\text{ N} = 2.42\text{ kN}$ **Ans.**

$F_R = 3461.53\text{ N} = 3.46\text{ kN}$ **Ans.**



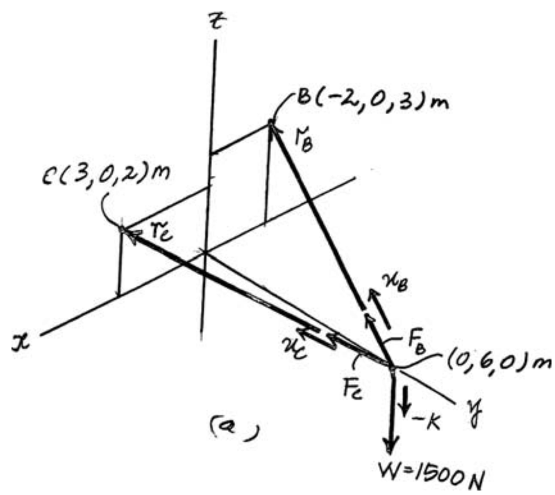
***2–100.** Two cables are used to secure the overhang boom in position and support the 1500-N load. If the resultant force is directed along the boom from point A towards O, determine the values of x and z for the coordinates of point C and the magnitude of the resultant force. Set $F_B = 1610$ N and $F_C = 2400$ N.



Force Vectors: From Fig. *a*,

$$\mathbf{u}_B = \frac{\mathbf{r}_B}{r_B} = \frac{(-2-0)\mathbf{i}+(0-6)\mathbf{j}+(3-0)\mathbf{k}}{\sqrt{(-2-0)^2+(0-6)^2+(3-0)^2}} = -\frac{2}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{3}{7}\mathbf{k}$$

$$\mathbf{u}_C = \frac{\mathbf{r}_C}{r_C} = \frac{(x-0)\mathbf{i}+(0-6)\mathbf{j}+(z-0)\mathbf{k}}{\sqrt{(x-0)^2+(0-6)^2+(z-0)^2}} = \frac{x}{\sqrt{x^2+z^2+36}}\mathbf{i}-\frac{6}{\sqrt{x^2+z^2+36}}\mathbf{j}+\frac{z}{\sqrt{x^2+z^2+36}}\mathbf{k}$$



Thus,

$$\mathbf{F}_B = F_B\mathbf{u}_B = 1610\left(-\frac{2}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{3}{7}\mathbf{k}\right) = [-460\mathbf{i}-1380\mathbf{j}+690\mathbf{k}]\text{ N}$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = 2400\left(\frac{x}{\sqrt{x^2+z^2+36}}\mathbf{i}-\frac{6}{\sqrt{x^2+z^2+36}}\mathbf{j}+\frac{z}{\sqrt{x^2+z^2+36}}\mathbf{k}\right)$$

$$= \frac{2400x}{\sqrt{x^2+z^2+36}}\mathbf{i}-\frac{14\,400}{\sqrt{x^2+z^2+36}}\mathbf{j}+\frac{2400z}{\sqrt{x^2+z^2+36}}\mathbf{k}$$

Since the resultant force $\mathbf{F}_R$ is directed along the negative y axis, and the load is directed along the z axis, these two forces can be written as

$$\mathbf{F}_R = -F_R\mathbf{j} \qquad \text{and} \qquad \mathbf{W} = [-1500\mathbf{k}]\text{ N}$$

Resultant Force:

$$\mathbf{F}_R = \mathbf{F}_B + \mathbf{F}_C + \mathbf{W}$$

$$-F_R\mathbf{j} = (-460\mathbf{i}-1380\mathbf{j}+690\mathbf{k})+\left(\frac{2400x}{\sqrt{x^2+z^2+36}}\mathbf{i}-\frac{14\,400}{\sqrt{x^2+z^2+36}}\mathbf{j}+\frac{2400z}{\sqrt{x^2+z^2+36}}\mathbf{k}\right)+(-1500\mathbf{k})$$

$$-F_R\mathbf{j} = \left(\frac{2400x}{\sqrt{x^2+z^2+36}}-460\right)\mathbf{i}-\left(\frac{14\,400}{\sqrt{x^2+z^2+36}}+1380\right)\mathbf{j}+\left(690+\frac{2400z}{\sqrt{x^2+z^2+36}}-1500\right)\mathbf{k}$$

Equating the **i**, **j**, and **k** components,

$$0 = \frac{2400x}{\sqrt{x^2+z^2+36}}-460 \qquad \frac{2400x}{\sqrt{x^2+z^2+36}} = 460 \qquad (1)$$

$$-F_R = -\left(\frac{14400}{\sqrt{x^2+z^2+36}}+1380\right) \qquad F_R = \frac{14400}{\sqrt{x^2+z^2+36}}+1380 \qquad (2)$$

$$0 = 690+\frac{2400z}{\sqrt{x^2+z^2+36}}-1500 \qquad \frac{2400z}{\sqrt{x^2+z^2+36}} = 810 \qquad (3)$$

Dividing Eq. (1) by Eq. (3), yields

$$x = 0.5679z \qquad (4)$$

Substituting Eq. (4) into Eq. (1), and solving

$z = 2.197\text{ m} = 2.20\text{ m}$ **Ans.**

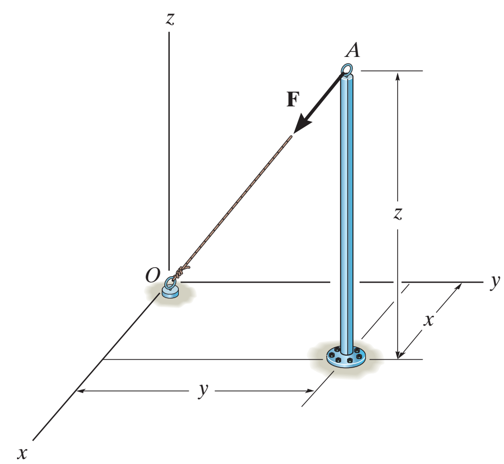
Substituting $z = 2.197$ m into Eq. (4), yields

$x = 1.248\text{ m} = 1.25\text{ m}$ **Ans.**

Substituting $x = 1.248$ m and $z = 2.197$ m into Eq. (2), yields

$F_R = 3591.85\text{ N} = 3.59\text{ kN}$ **Ans.**

•2–101. The cable *AO* exerts a force on the top of the pole of $\mathbf{F} = \{-120\mathbf{i} - 90\mathbf{j} - 80\mathbf{k}\}$ lb. If the cable has a length of 34 ft, determine the height z of the pole and the location (x, y) of its base.



$$F = \sqrt{(-120)^2 + (-90)^2 + (-80)^2} = 170 \text{ lb}$$

$$\mathbf{u} = \frac{\mathbf{F}}{F} = -\frac{120}{170}\mathbf{i} - \frac{90}{170}\mathbf{j} - \frac{80}{170}\mathbf{k}$$

$$\mathbf{r} = 34\,\mathbf{u} = \{-24\mathbf{i} - 18\mathbf{j} - 16\mathbf{k}\} \text{ ft}$$

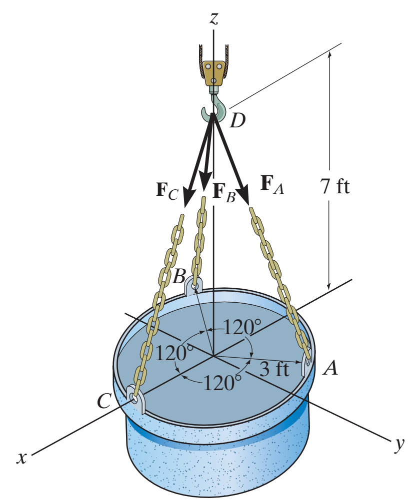
Thus,

$x = 24$ ft **Ans**

$y = 18$ ft **Ans**

$z = 16$ ft **Ans**

2–102. If the force in each chain has a magnitude of 450 lb, determine the magnitude and coordinate direction angles of the resultant force.



Force Vectors: The unit vectors $\mathbf{u}_A$, $\mathbf{u}_B$, and $\mathbf{u}_C$ must be determined first. From Fig. *a*,

$$\mathbf{u}_A = \frac{(-3\sin 30° - 0)\mathbf{i} + (3\cos 30° - 0)\mathbf{j} + (0-7)\mathbf{k}}{\sqrt{(-3\sin 30° - 0)^2 + (3\cos 30° - 0)^2 + (0-7)^2}} = -0.1970\mathbf{i} + 0.3411\mathbf{j} - 0.9191\mathbf{k}$$

$$\mathbf{u}_B = \frac{(-3\sin 30° - 0)\mathbf{i} + (-3\cos 30° - 0)\mathbf{j} + (0-7)\mathbf{k}}{\sqrt{(-3\sin 30° - 0)^2 + (-3\cos 30° - 0)^2 + (0-7)^2}} = -0.1970\mathbf{i} - 0.3411\mathbf{j} - 0.9191\mathbf{k}$$

$$\mathbf{u}_C = \frac{(3-0)\mathbf{i} + (0-0)\mathbf{j} + (0-7)\mathbf{k}}{\sqrt{(3-0)^2 + (0-0)^2 + (0-7)^2}} = 0.3939\mathbf{i} - 0.9191\mathbf{k}$$

Thus, the force vectors $\mathbf{F}_A$, $\mathbf{F}_B$, and $\mathbf{F}_C$ are given by

$$\mathbf{F}_A = F_A\mathbf{u}_A = 450(-0.1970\mathbf{i} + 0.3411\mathbf{j} - 0.9191\mathbf{k}) = \{-88.63\mathbf{i} + 153.51\mathbf{j} - 413.62\mathbf{k}\}\ \text{lb}$$

$$\mathbf{F}_B = F_B\mathbf{u}_B = 450(-0.1970\mathbf{i} - 0.3411\mathbf{j} - 0.9191\mathbf{k}) = \{-88.63\mathbf{i} - 153.51\mathbf{j} - 413.62\mathbf{k}\}\ \text{lb}$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = 450(0.3939\mathbf{i} - 0.9191\mathbf{k}) = \{177.26\mathbf{i} - 413.62\mathbf{k}\}\ \text{lb}$$

Resultant Force:

$$\mathbf{F}_R = \mathbf{F}_A + \mathbf{F}_B + \mathbf{F}_C = (-88.63\mathbf{i} + 153.51\mathbf{j} - 413.62\mathbf{k}) + (-88.63\mathbf{i} - 153.51\mathbf{j} - 413.62\mathbf{k}) + (177.26\mathbf{i} - 413.62\mathbf{k})$$
$$= \{-1240.85\mathbf{k}\}\ \text{lb}$$

The magnitude of $\mathbf{F}_R$ is

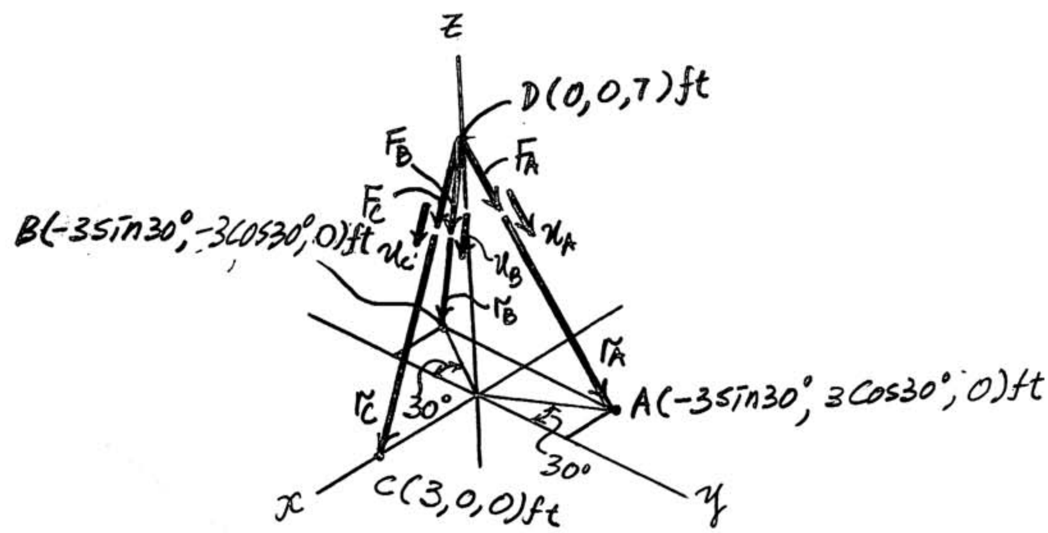
$$F_R = \sqrt{(F_R)_x^2 + (F_R)_y^2 + (F_R)_z^2}$$
$$= \sqrt{0^2 + 0^2 + (-1240.85)^2} = 1240.85\ \text{lb} = 1.24\ \text{kip} \qquad \textbf{Ans.}$$

The coordinate direction angles of $\mathbf{F}_R$ are

$$\alpha = \cos^{-1}\left[\frac{(F_R)_x}{F_R}\right] = \cos^{-1}\left(\frac{0}{1240.85}\right) = 90° \qquad \textbf{Ans.}$$

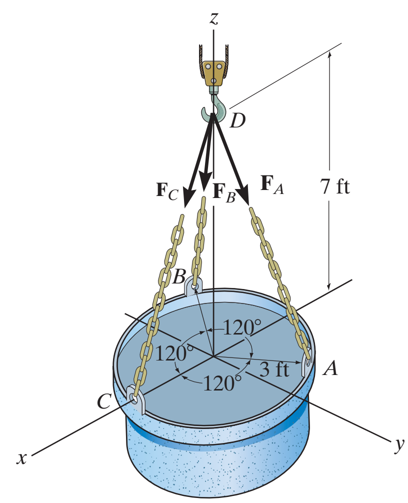
$$\beta = \cos^{-1}\left[\frac{(F_R)_y}{F_R}\right] = \cos^{-1}\left(\frac{0}{1240.85}\right) = 90° \qquad \textbf{Ans.}$$

$$\gamma = \cos^{-1}\left[\frac{(F_R)_z}{F_R}\right] = \cos^{-1}\left(\frac{-1240.85}{1240.85}\right) = 180° \qquad \textbf{Ans.}$$



(a)

2–103. If the resultant of the three forces is $\mathbf{F}_R = \{-900\mathbf{k}\}$ lb, determine the magnitude of the force in each chain.



Force Vectors: The unit vectors $\mathbf{u}_A$, $\mathbf{u}_B$, and $\mathbf{u}_C$ must be determined first. From Fig. *a*,

$$\mathbf{u}_A = \frac{(-3\sin 30° - 0)\mathbf{i} + (3\cos 30° - 0)\mathbf{j} + (0-7)\mathbf{k}}{\sqrt{(-3\sin 30° - 0)^2 + (3\cos 30° - 0)^2 + (0-7)^2}} = -0.1970\mathbf{i} + 0.3411\mathbf{j} - 0.9191\mathbf{k}$$

$$\mathbf{u}_B = \frac{(-3\sin 30° - 0)\mathbf{i} + (-3\cos 30° - 0)\mathbf{j} + (0-7)\mathbf{k}}{\sqrt{(-3\sin 30° - 0)^2 + (-3\cos 30° - 0)^2 + (0-7)^2}} = -0.1970\mathbf{i} - 0.3411\mathbf{j} - 0.9191\mathbf{k}$$

$$\mathbf{u}_C = \frac{(3-0)\mathbf{i} + (0-0)\mathbf{j} + (0-7)\mathbf{k}}{\sqrt{(3-0)^2 + (0-0)^2 + (0-7)^2}} = 0.3939\mathbf{i} - 0.9191\mathbf{k}$$

Thus, the force vectors $\mathbf{F}_A$, $\mathbf{F}_B$, and $\mathbf{F}_C$ are given by

$$\mathbf{F}_A = F_A\mathbf{u}_A = -0.1970F_A\mathbf{i} + 0.3411F_A\mathbf{j} - 0.9191F_A\mathbf{k}$$

$$\mathbf{F}_B = F_B\mathbf{u}_B = -0.1970F_B\mathbf{i} - 0.3411F_B\mathbf{j} - 0.9191F_B\mathbf{k}$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = 0.3939F_C\mathbf{i} - 0.9191F_C\mathbf{k}$$

Resultant Force: The vector addition of $\mathbf{F}_A$, $\mathbf{F}_B$, and $\mathbf{F}_C$ is equal to $\mathbf{F}_R$. Thus,

$$\mathbf{F}_R = \mathbf{F}_A + \mathbf{F}_B + \mathbf{F}_C$$

$$-900\mathbf{k} = (-0.1970F_A\mathbf{i} + 0.3411F_A\mathbf{j} - 0.9191F_A\mathbf{k}) + (-0.1970F_B\mathbf{i} - 0.3411F_B\mathbf{j} - 0.9191F_B\mathbf{k}) + (0.3939F_C\mathbf{i} - 0.9191F_C\mathbf{k})$$

$$-900\mathbf{k} = (-0.1970F_A - 0.1970F_B + 0.3939F_C)\mathbf{i} + (0.3411F_A - 0.3411F_B)\mathbf{j} + (-0.9191F_A - 0.9191F_B - 0.9191F_C)\mathbf{k}$$

Equating the **i**, **j**, and **k** components,

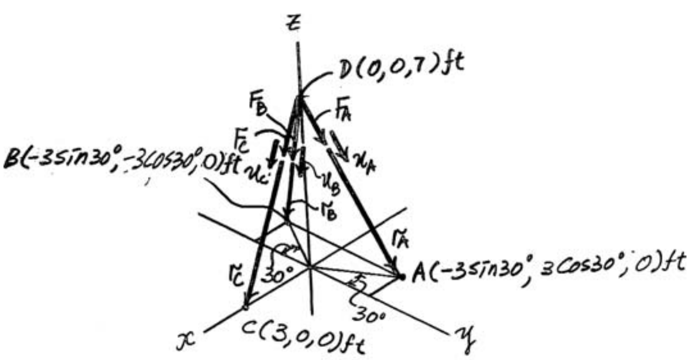
$$0 = -0.1970F_A - 0.1970F_B + 0.3939F_C \qquad (1)$$

$$0 = 0.3411F_A - 0.3411F_B \qquad (2)$$

$$-900\mathbf{k} = -0.9191F_A - 0.9191F_B - 0.9191F_C \qquad (3)$$

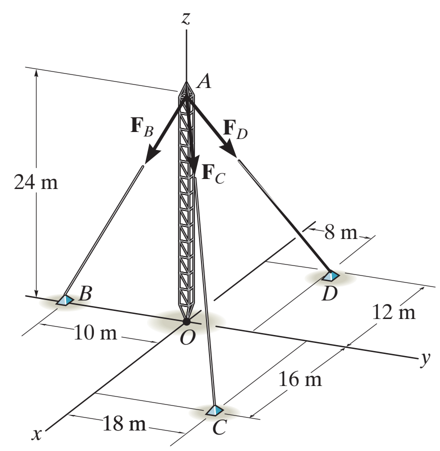
Solving Eqs. (1), (2), and (3), yields

$$F_A = F_B = F_C = 326 \text{ lb}$$ **Ans.**



(a)

***2–104.** The antenna tower is supported by three cables. If the forces of these cables acting on the antenna are $F_B = 520$ N, $F_C = 680$ N, and $F_D = 560$ N, determine the magnitude and coordinate direction angles of the resultant force acting at A.



$$\mathbf{F}_B = 520\left(\frac{\mathbf{r}_{AB}}{r_{AB}}\right) = 520\left(-\frac{10}{26}\mathbf{j} - \frac{24}{26}\mathbf{k}\right) = -200\,\mathbf{j} - 480\,\mathbf{k}$$

$$\mathbf{F}_C = 680\left(\frac{\mathbf{r}_{AC}}{r_{AC}}\right) = 680\left(\frac{16}{34}\mathbf{i} + \frac{18}{34}\mathbf{j} - \frac{24}{34}\mathbf{k}\right) = 320\,\mathbf{i} + 360\,\mathbf{j} - 480\,\mathbf{k}$$

$$\mathbf{F}_D = 560\left(\frac{\mathbf{r}_{AD}}{r_{AD}}\right) = 560\left(-\frac{12}{28}\mathbf{i} + \frac{8}{28}\mathbf{j} - \frac{24}{28}\mathbf{k}\right) = -240\,\mathbf{i} + 160\,\mathbf{j} - 480\,\mathbf{k}$$

$$\mathbf{F}_R = \Sigma\mathbf{F} = \{80\,\mathbf{i} + 320\,\mathbf{j} - 1440\,\mathbf{k}\}\text{ N}$$

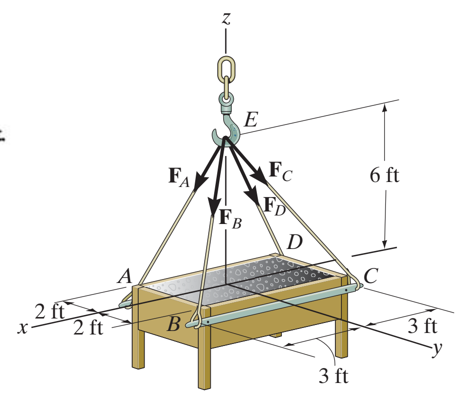
$$F_R = \sqrt{(80)^2 + (320)^2 + (-1440)^2} = 1477.3 = 1.48\text{ kN} \qquad \textbf{Ans}$$

$$\alpha = \cos^{-1}\left(\frac{80}{1477.3}\right) = 86.9^\circ \qquad \textbf{Ans}$$

$$\beta = \cos^{-1}\left(\frac{320}{1477.3}\right) = 77.5^\circ \qquad \textbf{Ans}$$

$$\gamma = \cos^{-1}\left(\frac{-1440}{1477.3}\right) = 167^\circ \qquad \textbf{Ans}$$

•2–105. If the force in each cable tied to the bin is 70 lb, determine the magnitude and coordinate direction angles of the resultant force.



Force Vectors: The unit vectors $\mathbf{u}_A$, $\mathbf{u}_B$, $\mathbf{u}_C$ and $\mathbf{u}_D$ of $\mathbf{F}_A$, $\mathbf{F}_B$, $\mathbf{F}_C$ and $\mathbf{F}_D$ must be determined first. From Fig. *a*,

$$\mathbf{u}_A = \frac{\mathbf{r}_A}{r_A} = \frac{(3-0)\mathbf{i}+(-2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(3-0)^2+(-2-0)^2+(0-6)^2}} = \frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

$$\mathbf{u}_B = \frac{\mathbf{r}_B}{r_B} = \frac{(3-0)\mathbf{i}+(2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(3-0)^2+(2-0)^2+(0-6)^2}} = \frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

$$\mathbf{u}_C = \frac{\mathbf{r}_C}{r_C} = \frac{(-3-0)\mathbf{i}+(2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(-3-0)^2+(2-0)^2+(0-6)^2}} = -\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

$$\mathbf{u}_D = \frac{\mathbf{r}_D}{r_D} = \frac{(-3-0)\mathbf{i}+(-2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(-3-0)^2+(-2-0)^2+(0-6)^2}} = -\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

Thus, the force vectors $\mathbf{F}_A$, $\mathbf{F}_B$, $\mathbf{F}_C$ and $\mathbf{F}_D$ are given by

$$\mathbf{F}_A = F_A\mathbf{u}_A = 70\left(\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right) = [30\mathbf{i}-20\mathbf{j}-60\mathbf{k}]\text{ lb}$$

$$\mathbf{F}_B = F_B\mathbf{u}_B = 70\left(\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right) = [30\mathbf{i}+20\mathbf{j}-60\mathbf{k}]\text{ lb}$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = 70\left(-\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right) = [-30\mathbf{i}+20\mathbf{j}-60\mathbf{k}]\text{ lb}$$

$$\mathbf{F}_D = F_D\mathbf{u}_D = 70\left(-\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right) = [-30\mathbf{i}-20\mathbf{j}-60\mathbf{k}]\text{ lb}$$

Resultant Force:

$$\mathbf{F}_R = \mathbf{F}_A+\mathbf{F}_B+\mathbf{F}_C+\mathbf{F}_D = (30\mathbf{i}-20\mathbf{j}-60\mathbf{k})+(30\mathbf{i}+20\mathbf{j}-60\mathbf{k})+(-30\mathbf{i}+20\mathbf{j}-60\mathbf{k})+(-30\mathbf{i}-20\mathbf{j}-60\mathbf{k})$$
$$=\{-240\mathbf{k}\}\text{ N}$$

The magnitude of $\mathbf{F}_R$ is

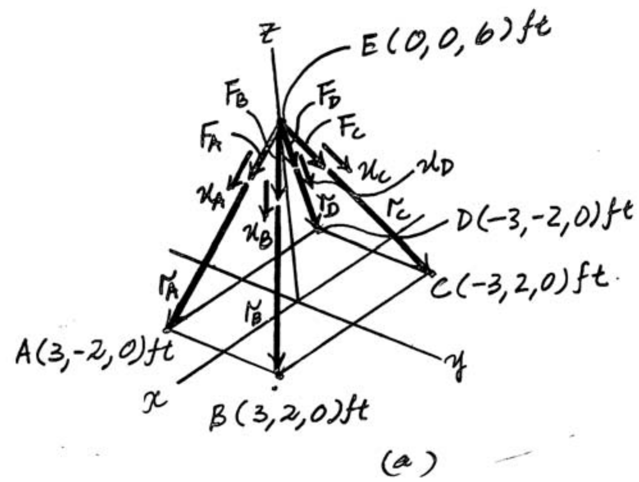
$$F_R = \sqrt{(F_R)_x^2+(F_R)_y^2+(F_R)_z^2}$$
$$= \sqrt{0+0+(-240)^2} = 240\text{ lb} \qquad \textbf{Ans.}$$

The coordinate direction angles of $\mathbf{F}_R$ are

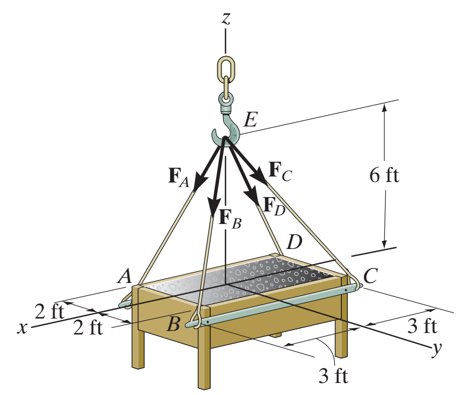
$$\alpha = \cos^{-1}\left[\frac{(F_R)_x}{F_R}\right] = \cos^{-1}\left(\frac{0}{240}\right) = 90° \qquad \textbf{Ans.}$$

$$\beta = \cos^{-1}\left[\frac{(F_R)_y}{F_R}\right] = \cos^{-1}\left(\frac{0}{240}\right) = 90° \qquad \textbf{Ans.}$$

$$\gamma = \cos^{-1}\left[\frac{(F_R)_z}{F_R}\right] = \cos^{-1}\left(\frac{-240}{240}\right) = 180° \qquad \textbf{Ans.}$$



2–106. If the resultant of the four forces is $\mathbf{F}_R = \{-360\mathbf{k}\}$ lb, determine the tension developed in each cable. Due to symmetry, the tension in the four cables is the same.



Force Vectors: The unit vectors $\mathbf{u}_A$, $\mathbf{u}_B$, $\mathbf{u}_C$ and $\mathbf{u}_D$ of $\mathbf{F}_A$, $\mathbf{F}_B$, $\mathbf{F}_C$ and $\mathbf{F}_D$ must be determined first. From Fig. *a*,

$$\mathbf{u}_A = \frac{\mathbf{r}_A}{r_A} = \frac{(3-0)\mathbf{i}+(-2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(3-0)^2+(-2-0)^2+(0-6)^2}} = \frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

$$\mathbf{u}_B = \frac{\mathbf{r}_B}{r_B} = \frac{(3-0)\mathbf{i}+(2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(3-0)^2+(2-0)^2+(0-6)^2}} = \frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

$$\mathbf{u}_C = \frac{\mathbf{r}_C}{r_C} = \frac{(-3-0)\mathbf{i}+(2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(-3-0)^2+(2-0)^2+(0-6)^2}} = -\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

$$\mathbf{u}_D = \frac{\mathbf{r}_D}{r_D} = \frac{(-3-0)\mathbf{i}+(-2-0)\mathbf{j}+(0-6)\mathbf{k}}{\sqrt{(-3-0)^2+(-2-0)^2+(0-6)^2}} = -\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}$$

Since the magnitudes of $\mathbf{F}_A$, $\mathbf{F}_B$, $\mathbf{F}_C$ and $\mathbf{F}_D$ are the same and denoted as $\mathbf{F}$, they can be written as

$$\mathbf{F}_A = F_A\mathbf{u}_A = F\left(\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)$$

$$\mathbf{F}_B = F_B\mathbf{u}_B = F\left(\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)$$

$$\mathbf{F}_C = F_C\mathbf{u}_C = F\left(-\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)$$

$$\mathbf{F}_D = F_D\mathbf{u}_D = F\left(-\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)$$

Resultant Force: The vector addition of $\mathbf{F}_A$, $\mathbf{F}_B$, $\mathbf{F}_C$ and $\mathbf{F}_D$ is equal to $\mathbf{F}_R$. Thus,

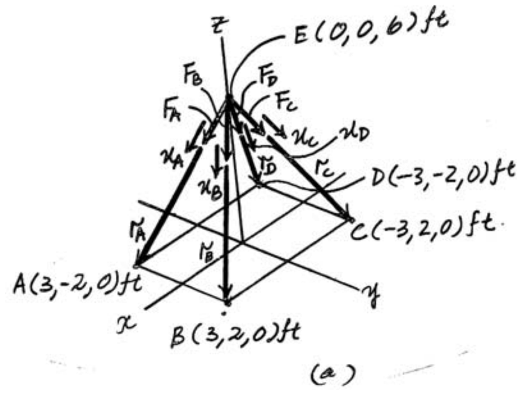
$$\mathbf{F}_R = \mathbf{F}_A + \mathbf{F}_B + \mathbf{F}_C + \mathbf{F}_D$$

$$\{-360\mathbf{k}\} = \left[F\left(\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)\right]+\left[F\left(\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)\right]+\left[F\left(-\frac{3}{7}\mathbf{i}+\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)\right]+\left[F\left(-\frac{3}{7}\mathbf{i}-\frac{2}{7}\mathbf{j}-\frac{6}{7}\mathbf{k}\right)\right]$$

$$-360\mathbf{k} = -\frac{24}{7}\mathbf{k}$$

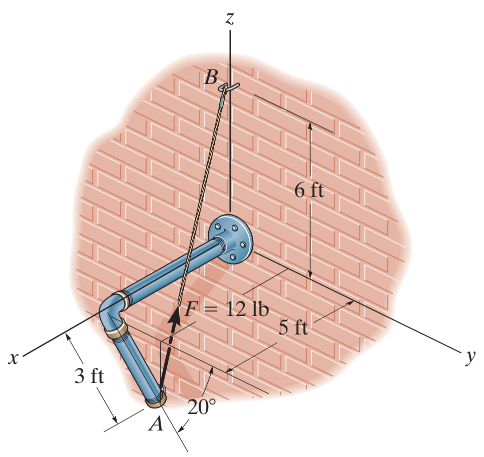
Thus,

$$360 = \frac{24}{7}F \qquad F = 105 \text{ lb} \qquad \textbf{Ans.}$$



(a)

2–107. The pipe is supported at its end by a cord AB. If the cord exerts a force of $F = 12$ lb on the pipe at A, express this force as a Cartesian vector.



Unit Vector : The coordinates of point A are

$$A(5,\ 3\cos 20°,\ -3\sin 20°)\ \text{ft} = A(5.00,\ 2.819,\ -1.026)\ \text{ft}$$

Then

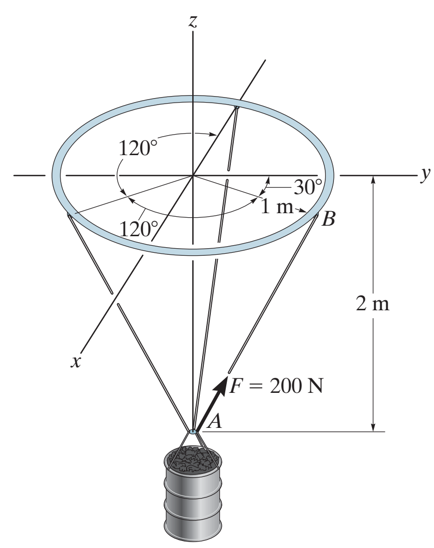
$$\mathbf{r}_{AB} = \{(0-5.00)\mathbf{i} + (0-2.819)\mathbf{j} + [6-(-1.026)]\mathbf{k}\}\ \text{ft}$$
$$= \{-5.00\mathbf{i} - 2.819\mathbf{j} + 7.026\mathbf{k}\}\ \text{ft}$$
$$r_{AB} = \sqrt{(-5.00)^2 + (-2.819)^2 + 7.026^2} = 9.073\ \text{ft}$$

$$\mathbf{u}_{AB} = \frac{\mathbf{r}_{AB}}{r_{AB}} = \frac{-5.00\mathbf{i} - 2.819\mathbf{j} + 7.026\mathbf{k}}{9.073}$$
$$= -0.5511\mathbf{i} - 0.3107\mathbf{j} + 0.7744\mathbf{k}$$

Force Vector :

$$\mathbf{F} = F\mathbf{u}_{AB} = 12\{-0.5511\mathbf{i} - 0.3107\mathbf{j} + 0.7744\mathbf{k}\}\ \text{lb}$$
$$= \{-6.61\mathbf{i} - 3.73\mathbf{j} + 9.29\mathbf{k}\}\ \text{lb} \qquad \textbf{Ans}$$

***2–108.** The load at A creates a force of 200 N in wire AB. Express this force as a Cartesian vector, acting on A and directed towards B.



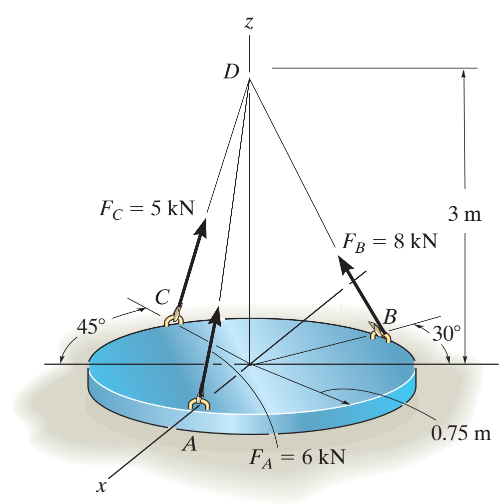
$$\mathbf{r}_{AB} = (1\sin 30° - 0)\mathbf{i} + (1\cos 30° - 0)\mathbf{j} + (2-0)\mathbf{k}$$
$$= \{0.5\,\mathbf{i} + 0.866\,\mathbf{j} + 2\mathbf{k}\}\text{m}$$

$$r_{AB} = \sqrt{(0.5)^2 + (0.866)^2 + (2)^2} = 2.236\ \text{m}$$

$$\mathbf{u}_{AB} = \left(\frac{\mathbf{r}_{AB}}{r_{AB}}\right) = 0.2236\mathbf{i} + 0.3873\,\mathbf{j} + 0.8944\,\mathbf{k}$$

$$\mathbf{F} = 200\,\mathbf{u}_{AB} = \{44.7\,\mathbf{i} + 77.5\,\mathbf{j} + 179\,\mathbf{k}\}\ \text{N} \qquad \textbf{Ans}$$

•2–109. The cylindrical plate is subjected to the three cable forces which are concurrent at point D. Express each force which the cables exert on the plate as a Cartesian vector, and determine the magnitude and coordinate direction angles of the resultant force.



$$\mathbf{r}_A = (0-0.75)\mathbf{i} + (0-0)\mathbf{j} + (3-0)\mathbf{k} = \{-0.75\,\mathbf{i} + 0\,\mathbf{j} + 3\,\mathbf{k}\}\text{ m}$$

$$r_A = \sqrt{(-0.75)^2 + 0^2 + 3^2} = 3.0923\text{ m}$$

$$\mathbf{F}_A = F_A\left(\frac{\mathbf{r}_A}{r_A}\right) = 6\left(\frac{-0.75\,\mathbf{i} + 3\,\mathbf{k}}{3.0923}\right)$$

$$= \{-1.4552\,\mathbf{i} + 5.8209\,\mathbf{k}\}\text{ kN}$$

$$= \{-1.46\,\mathbf{i} + 5.82\,\mathbf{k}\}\text{ kN} \qquad \textbf{Ans}$$

$$\mathbf{r}_C = \left[0-(-0.75\sin 45°)\right]\mathbf{i} + \left[0-(-0.75\cos 45°)\right]\mathbf{j} + (3-0)\mathbf{k}$$

$$= \{0.5303\,\mathbf{i} + 0.5303\,\mathbf{j} + 3\,\mathbf{k}\}\text{ m}$$

$$r_C = \sqrt{(0.5303)^2 + (0.5303)^2 + 3^2} = 3.0923\text{ m}$$

$$\mathbf{F}_C = F_C\left(\frac{\mathbf{r}_C}{r_C}\right) = 5\left(\frac{0.5303\,\mathbf{i} + 0.5303\,\mathbf{j} + 3\,\mathbf{k}}{3.0923}\right)$$

$$= \{0.8575\,\mathbf{i} + 0.8575\,\mathbf{j} + 4.8507\,\mathbf{k}\}\text{ kN}$$

$$= \{0.857\,\mathbf{i} + 0.857\,\mathbf{j} + 4.85\,\mathbf{k}\}\text{ kN} \qquad \textbf{Ans}$$

$$\mathbf{r}_B = \left[0-(-0.75\sin 30°)\right]\mathbf{i} + (0-0.75\cos 30°)\mathbf{j} + (3-0)\mathbf{k}$$

$$= \{0.375\,\mathbf{i} - 0.6495\,\mathbf{j} + 3\,\mathbf{k}\}\text{ m}$$

$$r_B = \sqrt{(0.375)^2 + (-0.6495)^2 + 3^2} = 3.0923\text{ m}$$

$$\mathbf{F}_B = F_B\left(\frac{\mathbf{r}_B}{r_B}\right) = 8\left(\frac{0.375\,\mathbf{i} - 0.6495\,\mathbf{j} + 3\,\mathbf{k}}{3.0923}\right)$$

$$= \{0.9701\mathbf{i} - 1.6803\mathbf{j} + 7.7611\mathbf{k}\}\text{ kN}$$

$$= \{0.970\mathbf{i} - 1.68\mathbf{j} + 7.76\mathbf{k}\}\text{ kN} \qquad \textbf{Ans}$$

$$\mathbf{F}_R = \mathbf{F}_A + \mathbf{F}_B + \mathbf{F}_C$$

$$= \{-1.4552\,\mathbf{i} + 5.8209\,\mathbf{k}\} + \{0.9701\,\mathbf{i} - 1.6803\,\mathbf{j} + 7.7611\mathbf{k}\}$$

$$+ \{0.8575\,\mathbf{i} + 0.8575\,\mathbf{j} + 4.8507\,\mathbf{k}\}$$

$$= \{0.3724\,\mathbf{i} - 0.8228\,\mathbf{j} + 18.4327\,\mathbf{k}\}\text{ kN}$$

$$F_R = \sqrt{(0.3724)^2 + (-0.8228)^2 + (18.4327)^2}$$

$$= 18.4548\text{ kN} = 18.5\text{ kN} \qquad \textbf{Ans}$$

$$\mathbf{u}_R = \frac{\mathbf{F}_R}{F_R} = \frac{0.3724\mathbf{i} - 0.8228\mathbf{j} + 18.4327\mathbf{k}}{18.4548}$$

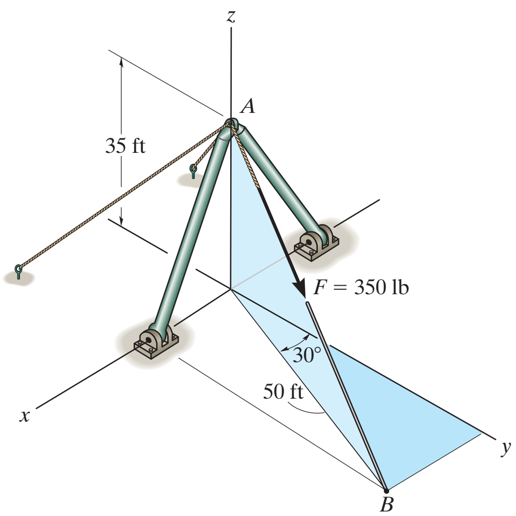
$$= 0.02018\mathbf{i} - 0.04459\mathbf{j} + 0.9988\mathbf{k}$$

$\cos\alpha = 0.02018 \qquad \alpha = 88.8° \qquad$ **Ans**

$\cos\beta = -0.04458 \qquad \beta = 92.6° \qquad$ **Ans**

$\cos\gamma = 0.9988 \qquad \gamma = 2.81° \qquad$ **Ans**

2–110. The cable attached to the shear-leg derrick exerts a force on the derrick of $F = 350$ lb. Express this force as a Cartesian vector.



Unit Vector : The coordinates of point B are

$$B(50\sin 30°,\ 50\cos 30°,\ 0)\ \text{ft} = B(25.0,\ 43.301,\ 0)\ \text{ft}$$

Then

$$\mathbf{r}_{AB} = \{(25.0-0)\mathbf{i} + (43.301-0)\mathbf{j} + (0-35)\mathbf{k}\}\ \text{ft}$$
$$= \{25.0\mathbf{i} + 43.301\mathbf{j} - 35.0\mathbf{k}\}\ \text{ft}$$
$$r_{AB} = \sqrt{25.0^2 + 43.301^2 + (-35.0)^2} = 61.033\ \text{ft}$$

$$\mathbf{u}_{AB} = \frac{\mathbf{r}_{AB}}{r_{AB}} = \frac{25.0\mathbf{i} + 43.301\mathbf{j} - 35.0\mathbf{k}}{61.033}$$
$$= 0.4096\mathbf{i} + 0.7094\mathbf{j} - 0.5735\mathbf{k}$$

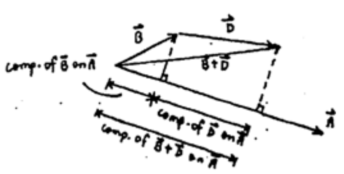
Force Vector :

$$\mathbf{F} = F\mathbf{u}_{AB} = 350\{0.4096\mathbf{i} + 0.7094\mathbf{j} - 0.5735\mathbf{k}\}\ \text{lb}$$
$$= \{143\mathbf{i} + 248\mathbf{j} - 201\mathbf{k}\}\ \text{lb} \qquad \textbf{Ans}$$

2–111. Given the three vectors A, B, and D, show that $\mathbf{A}\cdot(\mathbf{B}+\mathbf{D}) = (\mathbf{A}\cdot\mathbf{B}) + (\mathbf{A}\cdot\mathbf{D})$.

Since the component of $(\mathbf{B}+\mathbf{D})$ is equal to the sum of the components of $\mathbf{B}$ and $\mathbf{D}$, then

$$\mathbf{A}\cdot(\mathbf{B}+\mathbf{D}) = \mathbf{A}\cdot\mathbf{B} + \mathbf{A}\cdot\mathbf{D} \qquad \textbf{(QED)}$$



Also,

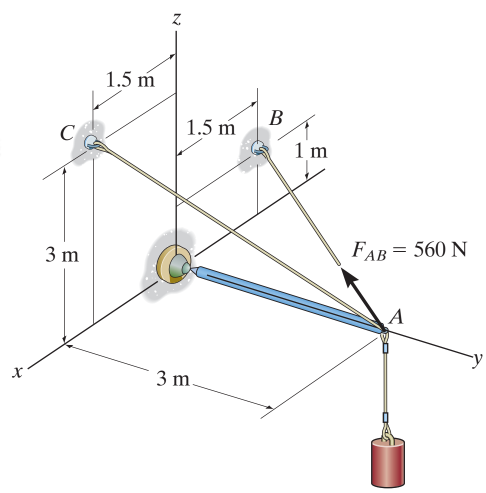
$$\mathbf{A}\cdot(\mathbf{B}+\mathbf{D}) = (A_x\mathbf{i} + A_y\mathbf{j} + A_z\mathbf{k})\cdot[(B_x + D_x)\mathbf{i} + (B_y + D_y)\mathbf{j} + (B_z + D_z)\mathbf{k}]$$

$$= A_x(B_x + D_x) + A_y(B_y + D_y) + A_z(B_z + D_z)$$

$$= (A_xB_x + A_yB_y + A_zB_z) + (A_xD_x + A_yD_y + A_zD_z)$$

$$= (\mathbf{A}\cdot\mathbf{B}) + (\mathbf{A}\cdot\mathbf{D}) \qquad \textbf{(QED)}$$

***2–112.** Determine the projected component of the force $F_{AB} = 560$ N acting along cable AC. Express the result as a Cartesian vector.



Force Vectors: The unit vectors $\mathbf{u}_{AB}$ and $\mathbf{u}_{AC}$ must be determined first. From Fig. *a*,

$$\mathbf{u}_{AB} = \frac{\mathbf{r}_{AB}}{r_{AB}} = \frac{(-1.5-0)\mathbf{i}+(0-3)\mathbf{j}+(1-0)\mathbf{k}}{\sqrt{(-1.5-0)^2+(0-3)^2+(1-0)^2}} = -\frac{3}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{2}{7}\mathbf{k}$$

$$\mathbf{u}_{AC} = \frac{\mathbf{r}_{AC}}{r_{AC}} = \frac{(1.5-0)\mathbf{i}+(0-3)\mathbf{j}+(3-0)\mathbf{k}}{\sqrt{(1.5-0)^2+(0-3)^2+(3-0)^2}} = \frac{1}{3}\mathbf{i}-\frac{2}{3}\mathbf{j}+\frac{2}{3}\mathbf{k}$$

Thus, the force vector $\mathbf{F}_{AB}$ is given by

$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{u}_{AB} = 560\left(-\frac{3}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{2}{7}\mathbf{k}\right) = [-240\mathbf{i}-480\mathbf{j}+160\mathbf{k}]\text{ N}$$

Vector Dot Product: The magnitude of the projected component of $\mathbf{F}_{AB}$ is

$$(F_{AB})_{AC} = \mathbf{F}_{AB}\cdot\mathbf{u}_{AC} = (-240\mathbf{i}-480\mathbf{j}+160\mathbf{k})\cdot\left(\frac{1}{3}\mathbf{i}-\frac{2}{3}\mathbf{j}+\frac{2}{3}\mathbf{k}\right)$$

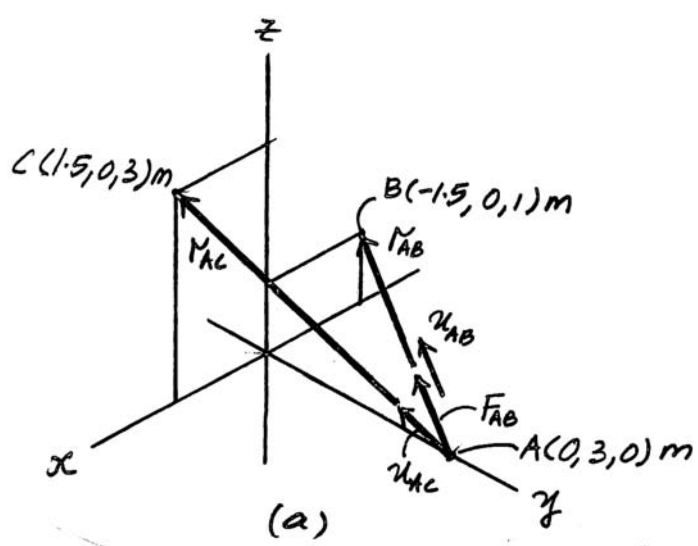
$$= (-240)\left(\frac{1}{3}\right)+(-480)\left(-\frac{2}{3}\right)+160\left(\frac{2}{3}\right)$$

$$= 346.67\text{ N}$$

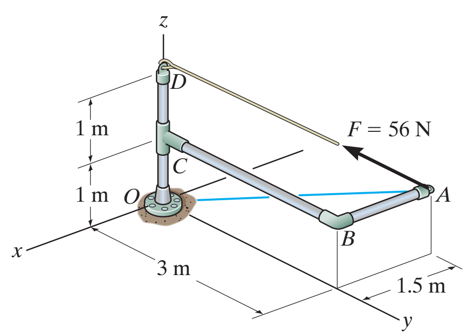
Thus, $(\mathbf{F}_{AB})_{AC}$ expressed in Cartesian vector form is

$$(\mathbf{F}_{AB})_{AC} = (F_{AB})_{AC}\,\mathbf{u}_{AC} = 346.67\left(\frac{1}{3}\mathbf{i}-\frac{2}{3}\mathbf{j}+\frac{2}{3}\mathbf{k}\right)$$

$$= [116\mathbf{i}-231\mathbf{j}+231\mathbf{k}]\text{N} \qquad \textbf{Ans.}$$



•2–113. Determine the magnitudes of the components of force $F = 56$ N acting along and perpendicular to line AO.



Unit Vectors: The unit vectors $\mathbf{u}_{AD}$ and $\mathbf{u}_{AO}$ must be determined first. From Fig. *a*,

$$\mathbf{u}_{AD} = \frac{\mathbf{r}_{AD}}{r_{AD}} = \frac{[0-(-1.5)]\mathbf{i}+(0-3)\mathbf{j}+(2-1)\mathbf{k}}{\sqrt{[0-(-1.5)]^2+(0-3)^2+(2-1)^2}} = \frac{3}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{2}{7}\mathbf{k}$$

$$\mathbf{u}_{AO} = \frac{\mathbf{r}_{AO}}{r_{AO}} = \frac{[0-(-1.5)]\mathbf{i}+(0-3)\mathbf{j}+(0-1)\mathbf{k}}{\sqrt{[0-(-1.5)]^2+(0-3)^2+(0-1)^2}} = \frac{3}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}-\frac{2}{7}\mathbf{k}$$

Thus, the force vector **F** is given by

$$\mathbf{F} = F\mathbf{u}_{AD} = 56\left(\frac{3}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}+\frac{2}{7}\mathbf{k}\right) = [24\mathbf{i}-48\mathbf{j}+16\mathbf{k}]\text{ N}$$

Vector Dot Product: The magnitude of the projected component of **F** parallel to line AO is

$$(F_{AO})_{\text{paral}} = \mathbf{F}\cdot\mathbf{u}_{AO} = (24\mathbf{i}-48\mathbf{j}+16\mathbf{k})\cdot\left(\frac{3}{7}\mathbf{i}-\frac{6}{7}\mathbf{j}-\frac{2}{7}\mathbf{k}\right)$$

$$= (24)\left(\frac{3}{7}\right)+(-48)\left(-\frac{6}{7}\right)+(16)\left(-\frac{2}{7}\right)$$

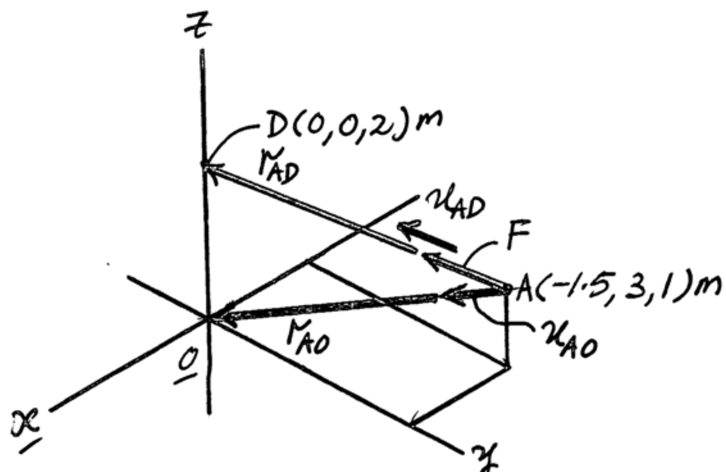
$$= 46.86\text{ N} = 46.9\text{ N} \qquad \textbf{Ans.}$$

The component of **F** perpendicular to line AO is

$$(F_{AO})_{\text{per}} = \sqrt{F^2-(F_{AO})_{\text{paral}}}$$

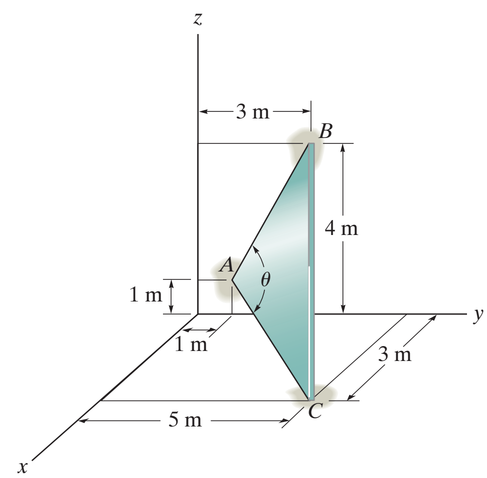
$$= \sqrt{56^2-46.86^2}$$

$$= 30.7\text{ N} \qquad \textbf{Ans.}$$



(a)

2–114. Determine the length of side BC of the triangular plate. Solve the problem by finding the magnitude of $\mathbf{r}_{BC}$; then check the result by first finding θ, r_{AB}, and r_{AC} and then using the cosine law.



$\mathbf{r}_{BC} = \{3\,\mathbf{i} + 2\,\mathbf{j} - 4\,\mathbf{k}\}$ m

$r_{BC} = \sqrt{(3)^2 + (2)^2 + (-4)^2} = 5.39$ m **Ans**

Also,

$\mathbf{r}_{AC} = \{3\,\mathbf{i} + 4\,\mathbf{j} - 1\,\mathbf{k}\}$ m

$r_{AC} = \sqrt{(3)^2 + (4)^2 + (-1)^2} = 5.0990$ m

$\mathbf{r}_{AB} = \{2\,\mathbf{j} + 3\,\mathbf{k}\}$ m

$r_{AB} = \sqrt{(2)^2 + (3)^2} = 3.6056$ m

$\mathbf{r}_{AC} \cdot \mathbf{r}_{AB} = 0 + 4(2) + (-1)(3) = 5$

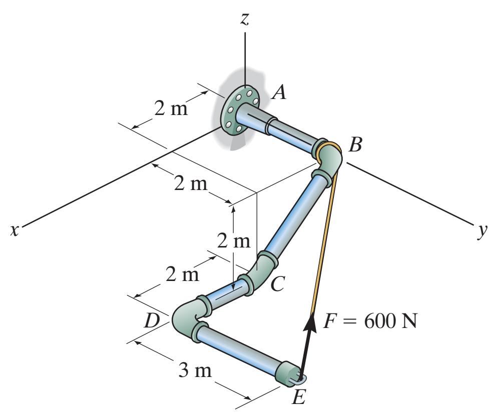
$$\theta = \cos^{-1}\left(\frac{\mathbf{r}_{AC} \cdot \mathbf{r}_{AB}}{r_{AC}r_{AB}}\right) = \cos^{-1}\frac{5}{(5.0990)(3.6056)}$$

$\theta = 74.219°$

$$r_{BC} = \sqrt{(5.0990)^2 + (3.6056)^2 - 2(5.0990)(3.6056)\cos 74.219°}$$

$r_{BC} = 5.39$ m **Ans**

2–115. Determine the magnitudes of the components of $F = 600$ N acting along and perpendicular to segment DE of the pipe assembly.



Unit Vectors: The unit vectors $\mathbf{u}_{EB}$ and $\mathbf{u}_{ED}$ must be determined first. From Fig. *a*,

$$\mathbf{u}_{EB} = \frac{\mathbf{r}_{EB}}{r_{EB}} = \frac{(0-4)\mathbf{i}+(2-5)\mathbf{j}+[0-(-2)]\mathbf{k}}{\sqrt{(0-4)^2+(2-5)^2+[0-(-2)]^2}} = -0.7428\mathbf{i}-0.5571\mathbf{j}+0.3714\mathbf{k}$$

$$\mathbf{u}_{ED} = -\mathbf{j}$$

Thus, the force vector **F** is given by

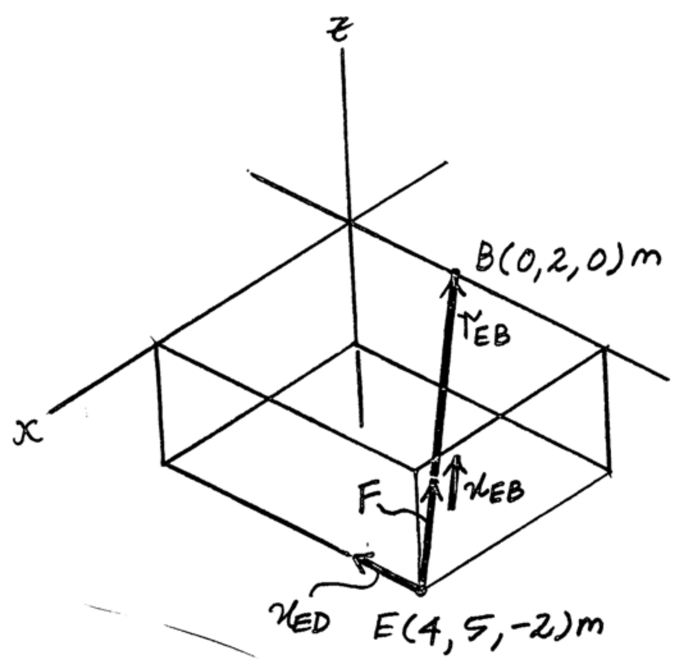
$$\mathbf{F} = F\mathbf{u}_{EB} = 600(-0.7428\mathbf{i}-0.5571\mathbf{j}+0.3714\mathbf{k}) = [-445.66\mathbf{i}-334.25\mathbf{j}+222.83\mathbf{k}]\text{ N}$$

Vector Dot Product: The magnitude of the component of **F** parallel to segment *DE* of the pipe assembly is

$$(F_{ED})_{\text{paral}} = \mathbf{F}\cdot\mathbf{u}_{ED} = (-445.66\mathbf{i}-334.25\mathbf{j}+222.83\mathbf{k})\cdot(-\mathbf{j})$$
$$= (-445.66)(0)+(-334.25)(-1)+(222.83)(0)$$
$$= 334.25 = 334\text{ N} \qquad \textbf{Ans.}$$

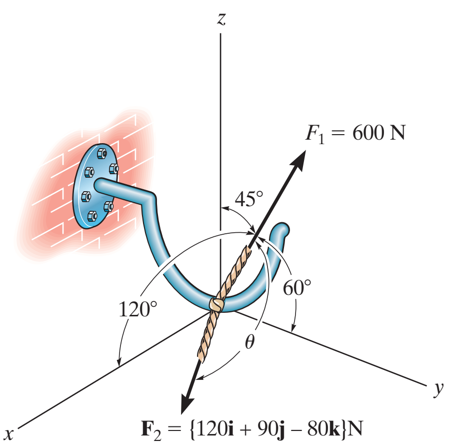
The component of **F** perpendicular to segment *DE* of the pipe assembly is

$$(F_{ED})_{\text{per}} = \sqrt{F^2-(F_{ED})_{\text{paral}}{}^2} = \sqrt{600^2-334.25^2} = 498\text{ N} \qquad \textbf{Ans.}$$



(a)

***2–116.** Two forces act on the hook. Determine the angle θ between them. Also, what are the projections of $\mathbf{F}_1$ and $\mathbf{F}_2$ along the y axis?



$$\mathbf{F}_1 = 600\cos 120°\,\mathbf{i} + 600\cos 60°\,\mathbf{j} + 600\cos 45°\,\mathbf{k}$$

$$= -300\,\mathbf{i} + 300\,\mathbf{j} + 424.3\,\mathbf{k}; \quad F_1 = 600\text{ N}$$

$$\mathbf{F}_2 = 120\,\mathbf{i} + 90\,\mathbf{j} - 80\,\mathbf{k}; \quad F_2 = 170\text{ N}$$

$$\mathbf{F}_1 \cdot \mathbf{F}_2 = (-300)(120) + (300)(90) + (424.3)(-80) = -42\,944$$

$$\theta = \cos^{-1}\left(\frac{-42\,944}{(170)(600)}\right) = 115° \qquad \textbf{Ans}$$

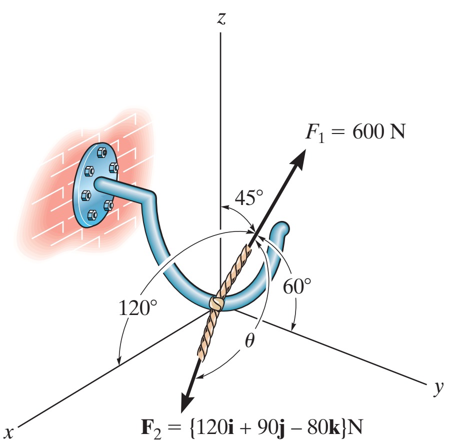
$$\mathbf{u} = \mathbf{j}$$

So,

$$F_{1y} = \mathbf{F}_1 \cdot \mathbf{j} = (300)(1) = 300\text{ N} \qquad \textbf{Ans}$$

$$F_{2y} = \mathbf{F}_2 \cdot \mathbf{j} = (90)(1) = 90\text{ N} \qquad \textbf{Ans}$$

•2–117. Two forces act on the hook. Determine the magnitude of the projection of $\mathbf{F}_2$ along $\mathbf{F}_1$.

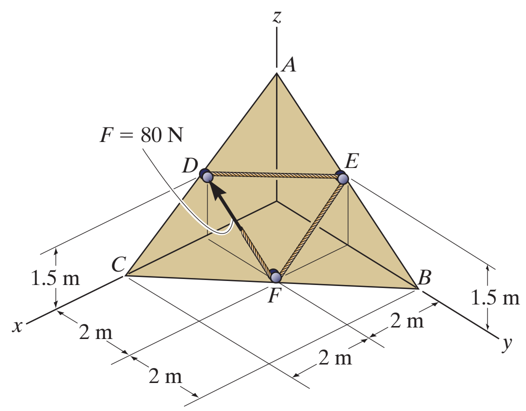


$$\mathbf{u}_1 = \cos 120°\,\mathbf{i} + \cos 60°\,\mathbf{j} + \cos 45°\,\mathbf{k}$$

$$\text{Proj } F_2 = \mathbf{F}_2 \cdot \mathbf{u}_1 = (120)(\cos 120°) + (90)(\cos 60°) + (-80)(\cos 45°)$$

$$|\text{Proj } F_2| = 71.6\text{ N} \qquad \textbf{Ans}$$

2–118. Determine the projection of force $F = 80$ N along line BC. Express the result as a Cartesian vector.



Unit Vectors: The unit vectors $\mathbf{u}_{FD}$ and $\mathbf{u}_{FC}$ must be determined first. From Fig. a,

$$\mathbf{u}_{FD} = \frac{\mathbf{r}_{FD}}{r_{FD}} = \frac{(2-2)\mathbf{i}+(0-2)\mathbf{j}+(1.5-0)\mathbf{k}}{\sqrt{(2-2)^2+(0-2)^2+(1.5-0)^2}} = -\frac{4}{5}\mathbf{j}+\frac{3}{5}\mathbf{k}$$

$$\mathbf{u}_{FC} = \frac{\mathbf{r}_{FC}}{r_{FC}} = \frac{(4-2)\mathbf{i}+(0-2)\mathbf{j}+(0-0)\mathbf{k}}{\sqrt{(4-2)^2+(0-2)^2+(0-0)^2}} = 0.7071\mathbf{i}-0.7071\mathbf{j}$$

Thus, the force vector $\mathbf{F}$ is given by

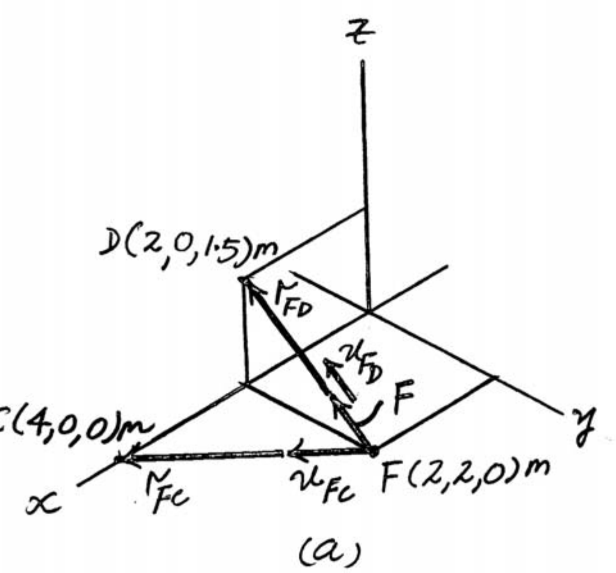
$$\mathbf{F} = F\mathbf{u}_{FD} = 80\left(-\frac{4}{5}\mathbf{j}+\frac{3}{5}\mathbf{k}\right) = [-64\mathbf{j}+48\mathbf{k}]\text{ N}$$

Vector Dot Product: The magnitude of the projected component of $\mathbf{F}$ along line BC is

$$F_{BC} = \mathbf{F}\cdot\mathbf{u}_{FC} = (-64\mathbf{j}+48\mathbf{k})\cdot(0.7071\mathbf{i}-0.7071\mathbf{j})$$
$$= (0)(0.7071)+(-64)(-0.7071)+48(0)$$
$$= 45.25 = 45.2\text{ N} \qquad \textbf{Ans.}$$

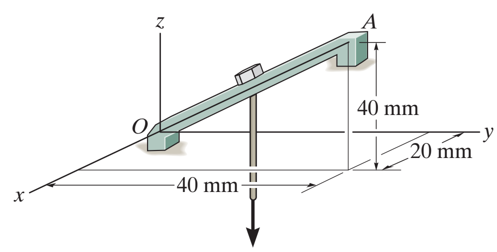
The component of $\mathbf{F}_{BC}$ can be expressed in Cartesian vector form as

$$\mathbf{F}_{BC} = F_{BC}(\mathbf{u}_{FC}) = 45.25(0.7071\mathbf{i}-0.7071\mathbf{j})$$
$$= \{32\mathbf{i}-32\mathbf{j}\}\text{ N} \qquad \textbf{Ans.}$$



(a)

2–119. The clamp is used on a jig. If the vertical force acting on the bolt is $\mathbf{F} = \{-500\mathbf{k}\}$ N, determine the magnitudes of its components $\mathbf{F}_1$ and $\mathbf{F}_2$ which act along the OA axis and perpendicular to it.



Unit Vector : The unit vector along OA axis is

$$\mathbf{u}_{AO} = \frac{(0-20)\,\mathbf{i} + (0-40)\,\mathbf{j} + (0-40)\,\mathbf{k}}{\sqrt{(0-20)^2 + (0-40)^2 + (0-40)^2}} = -\frac{1}{3}\mathbf{i} - \frac{2}{3}\mathbf{j} - \frac{2}{3}\mathbf{k}$$

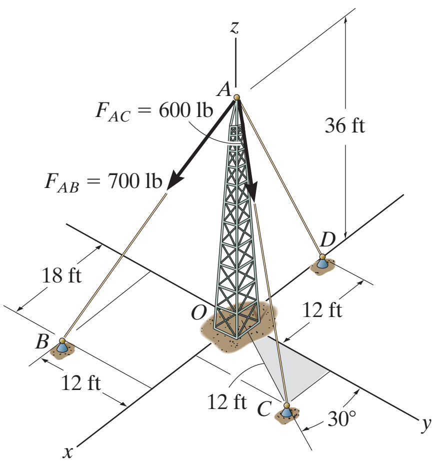
Projected Component of F Along OA Axis :

$$F_1 = \mathbf{F} \cdot \mathbf{u}_{AO} = (-500\mathbf{k}) \cdot \left(-\frac{1}{3}\mathbf{i} - \frac{2}{3}\mathbf{j} - \frac{2}{3}\mathbf{k}\right)$$
$$= (0)\left(-\frac{1}{3}\right) + (0)\left(-\frac{2}{3}\right) + (-500)\left(-\frac{2}{3}\right)$$
$$= 333.33 \text{ N} = 333 \text{ N} \qquad \textbf{Ans}$$

Component of F Perpendicular to OA Axis : Since the magnitude of force **F** is $F = 500$ N so that

$$F_2 = \sqrt{F^2 - F_1^2} = \sqrt{500^2 - 333.33^2} = 373 \text{ N} \qquad \textbf{Ans}$$

***2–120.** Determine the magnitude of the projected component of force $\mathbf{F}_{AB}$ acting along the z axis.



Unit Vector: The unit vector $\mathbf{u}_{AB}$ must be determined first. From Fig. *a*,

$$\mathbf{u}_{AB} = \frac{\mathbf{r}_{AB}}{r_{AB}} = \frac{(18-0)\mathbf{i} + (-12-0)\mathbf{j} + (0-36)\mathbf{k}}{\sqrt{(18-0)^2 + (-12-0)^2 + (0-36)^2}} = \frac{3}{7}\mathbf{i} - \frac{2}{7}\mathbf{j} - \frac{6}{7}\mathbf{k}$$

Thus, the force vector $\mathbf{F}_{AB}$ is given by

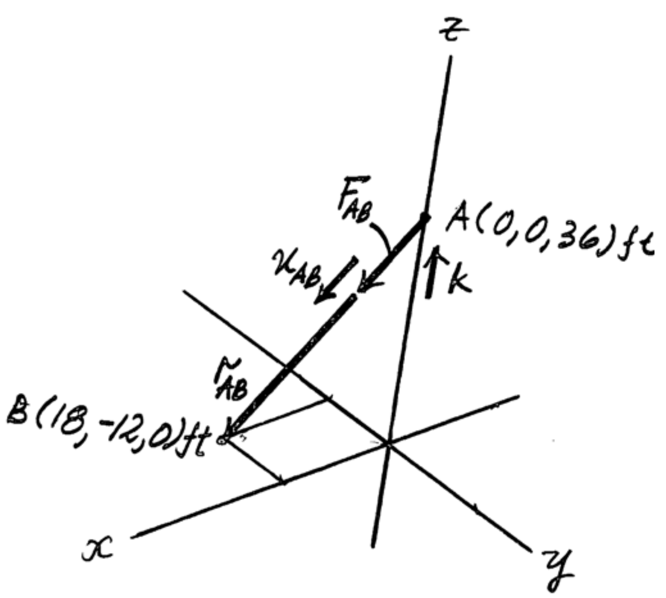
$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{u}_{AB} = 700\left(\frac{3}{7}\mathbf{i} - \frac{2}{7}\mathbf{j} - \frac{6}{7}\mathbf{k}\right) = \{300\mathbf{i} - 200\mathbf{j} - 600\mathbf{k}\}\text{ lb}$$

Vector Dot Product: The projected component of $\mathbf{F}_{AB}$ along the z axis is

$$(F_{AB})_z = \mathbf{F}_{AB}\cdot\mathbf{k} = (300\mathbf{i} - 200\mathbf{j} - 600\mathbf{k})\cdot\mathbf{k}$$
$$= -600\text{ lb}$$

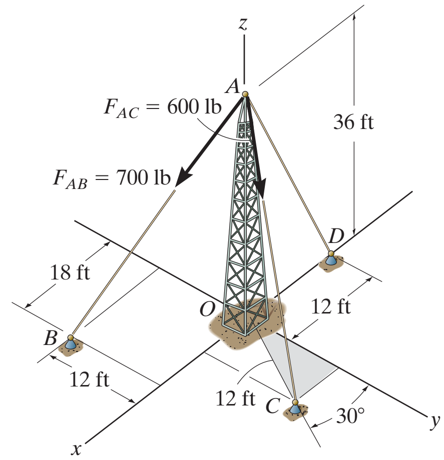
The negative sign indicates that $(\mathbf{F}_{AB})_z$ is directed towards the negative z axis. Thus

$(F_{AB})_z = 600$ lb **Ans.**



(a)

•**2–121.** Determine the magnitude of the projected component of force $\mathbf{F}_{AC}$ acting along the z axis.



Unit Vector: The unit vector $\mathbf{u}_{AC}$ must be determined first. From Fig. a,

$$\mathbf{u}_{AC} = \frac{\mathbf{r}_{AC}}{r_{AC}} = \frac{(12\sin 30° - 0)\mathbf{i} + (12\cos 30° - 0)\mathbf{j} + (0-36)\mathbf{k}}{\sqrt{(12\sin 30° - 0)^2 + (12\cos 30° - 0)^2 + (0-36)^2}} = 0.1581\mathbf{i} + 0.2739\mathbf{j} - 0.9487\mathbf{k}$$

Thus, the force vector $\mathbf{F}_{AC}$ is given by

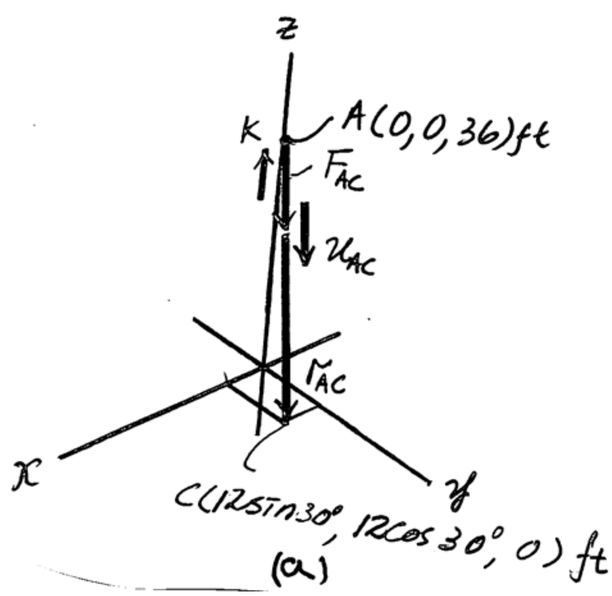
$$\mathbf{F}_{AC} = F_{AC}\mathbf{u}_{AC} = 600(0.1581\mathbf{i} + 0.2739\mathbf{j} - 0.9487\mathbf{k}) = \{94.87\mathbf{i} + 164.32\mathbf{j} - 569.21\mathbf{k}\}\text{N}$$

Vector Dot Product: The projected component of $\mathbf{F}_{AC}$ along the z axis is

$$(F_{AC})_z = \mathbf{F}_{AC} \cdot \mathbf{k} = (94.87\mathbf{i} + 164.32\mathbf{j} - 569.21\mathbf{k}) \cdot \mathbf{k}$$
$$= -569 \text{ lb}$$

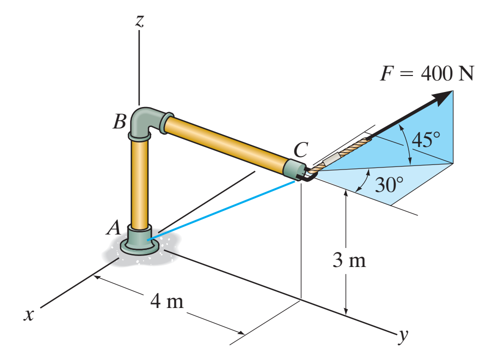
The negative sign indicates that $(\mathbf{F}_{AC})_z$ is directed towards the negative z axis. Thus

$(F_{AC})_z = 569$ lb **Ans.**



(a)

2–122. Determine the projection of force $F = 400$ N acting along line AC of the pipe assembly. Express the result as a Cartesian vector.



Force and unit Vector: The force vector **F** and unit vector $\mathbf{u}_{AC}$ must be determined first. From Fig. (*a*)

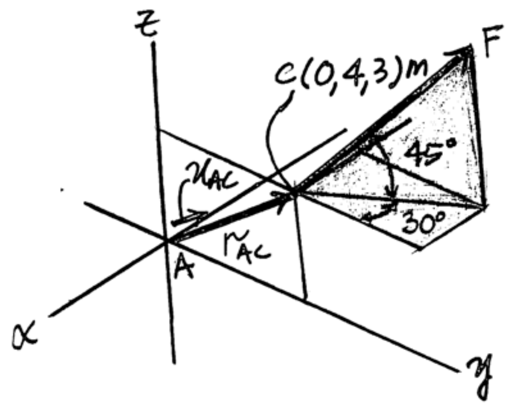
$$\mathbf{F} = 400(-\cos 45° \sin 30° \mathbf{i} + \cos 45° \cos 30° \mathbf{j} + \sin 45° \mathbf{k})$$
$$= \{-141.42\mathbf{i} + 244.95\mathbf{j} + 282.84\mathbf{k}\}$$
$$\mathbf{u}_{AC} = \frac{\mathbf{r}_{AC}}{r_{AC}} = \frac{(0-0)\mathbf{i} + (4-0)\mathbf{j} + (3-0)\mathbf{k}}{\sqrt{(0-0)^2 + (4-0)^2 + (3-0)^2}} = \frac{4}{5}\mathbf{j} + \frac{3}{5}\mathbf{k}$$

Vector Dot Product: The magnitude of the projected component of **F** along line AC is

$$F_{AC} = \mathbf{F} \cdot \mathbf{u}_{AC} = (-141.42\mathbf{i} + 244.95\mathbf{j} + 282.84\mathbf{k}) \cdot \left(\frac{4}{5}\mathbf{j} + \frac{3}{5}\mathbf{k}\right)$$
$$= (-141.42)(0) + 244.95\left(\frac{4}{5}\right) + 282.84\left(\frac{3}{5}\right)$$
$$= 365.66 \text{ lb}$$ **Ans.**

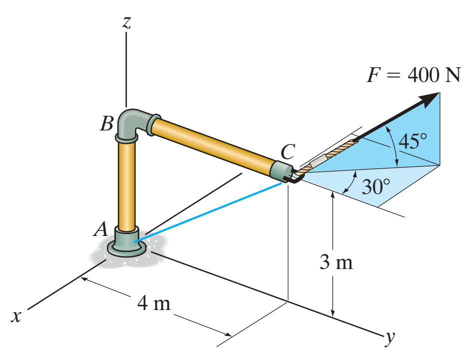
Thus, $\mathbf{F}_{AC}$ written in Cartesian vector form is

$$\mathbf{F}_{AC} = F_{AC}\mathbf{u}_{AC} = 365.66\left(\frac{4}{5}\mathbf{j} + \frac{3}{5}\mathbf{k}\right) = \{293\mathbf{j} + 219\mathbf{k}\} \text{ lb}$$ **Ans.**



(a)

2–123. Determine the magnitudes of the components of force $F = 400$ N acting parallel and perpendicular to segment BC of the pipe assembly.



Force Vector: The force vector **F** must be determined first. From Fig. *a*,

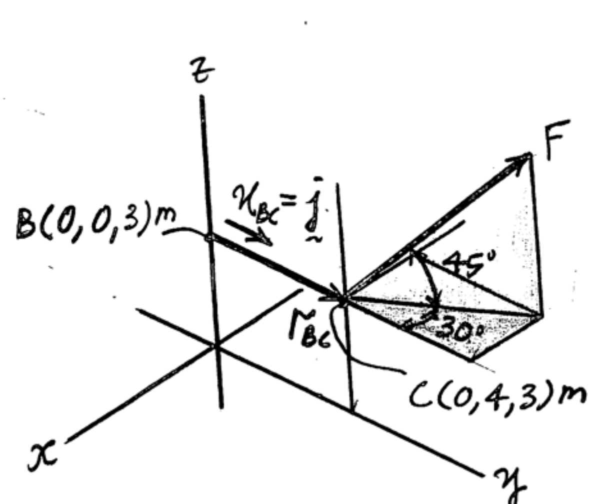
$$\mathbf{F} = 400(-\cos 45° \sin 30° \mathbf{i} + \cos 45° \cos 30° \mathbf{j} + \sin 45° \mathbf{k})$$
$$= \{-141.42\mathbf{i} + 244.95\mathbf{j} + 282.84\mathbf{k}\} \text{ N}$$

Vector Dot Product: By inspecting Fig. (*a*) we notice that $\mathbf{u}_{BC} = \mathbf{j}$. Thus, the magnitude of the component of **F** parallel to segment BC of the pipe assembly is

$$(F_{BC})_{\text{paral}} = \mathbf{F} \cdot \mathbf{j} = (-141.42\mathbf{i} + 244.95\mathbf{j} + 282.84\mathbf{k}) \cdot \mathbf{j}$$
$$= -141.42(0) + 244.95(1) + 282.84(0)$$
$$= 244.95 \text{ lb} = 245 \text{ N} \qquad \textbf{Ans.}$$

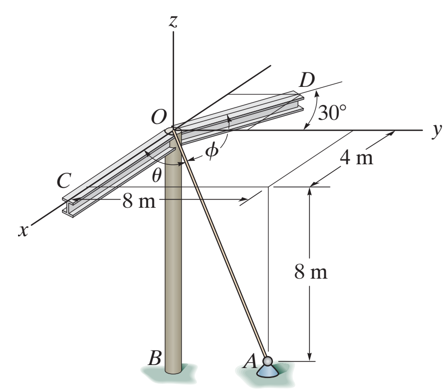
The magnitude of the component of **F** perpendicular to segment BC of the pipe assembly can be determined from

$$(F_{BC})_{\text{per}} = \sqrt{F^2 - (F_{BC})_{\text{paral}}^2} = \sqrt{400^2 - 244.95^2} = 316 \text{ N} \qquad \textbf{Ans.}$$



(a)

*2–124. Cable *OA* is used to support column *OB*. Determine the angle θ it makes with beam *OC*.



Unit Vector :

$$\mathbf{u}_{OC} = 1\mathbf{i}$$

$$\mathbf{u}_{OA} = \frac{(4-0)\mathbf{i}+(8-0)\mathbf{j}+(-8-0)\mathbf{k}}{\sqrt{(4-0)^2+(8-0)^2+(-8-0)^2}} = \frac{1}{3}\mathbf{i}+\frac{2}{3}\mathbf{j}-\frac{2}{3}\mathbf{k}$$

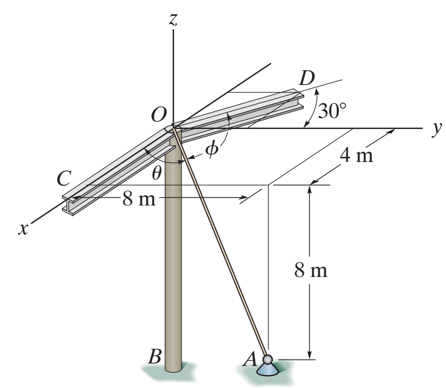
The Angle Between Two Vectors θ :

$$\mathbf{u}_{OC}\cdot\mathbf{u}_{OA} = (1\mathbf{i})\cdot\left(\frac{1}{3}\mathbf{i}+\frac{2}{3}\mathbf{j}-\frac{2}{3}\mathbf{k}\right) = 1\left(\frac{1}{3}\right)+(0)\left(\frac{2}{3}\right)+0\left(-\frac{2}{3}\right) = \frac{1}{3}$$

Then,

$$\theta = \cos^{-1}(\mathbf{u}_{OC}\cdot\mathbf{u}_{OA}) = \cos^{-1}\frac{1}{3} = 70.5^\circ \qquad \textbf{Ans}$$

•2–125. Cable *OA* is used to support column *OB*. Determine the angle ϕ it makes with beam *OD*.



Unit Vector :

$$\mathbf{u}_{OD} = -\sin 30^\circ\mathbf{i}+\cos 30^\circ\mathbf{j} = -0.5\mathbf{i}+0.8660\mathbf{j}$$

$$\mathbf{u}_{OA} = \frac{(4-0)\mathbf{i}+(8-0)\mathbf{j}+(-8-0)\mathbf{k}}{\sqrt{(4-0)^2+(8-0)^2+(-8-0)^2}} = \frac{1}{3}\mathbf{i}+\frac{2}{3}\mathbf{j}-\frac{2}{3}\mathbf{k}$$

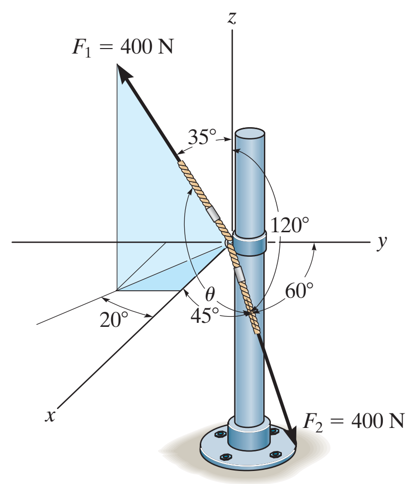
The Angles Between Two Vectors ϕ :

$$\begin{aligned}\mathbf{u}_{OD}\cdot\mathbf{u}_{OA} &= (-0.5\mathbf{i}+0.8660\mathbf{j})\cdot\left(\frac{1}{3}\mathbf{i}+\frac{2}{3}\mathbf{j}-\frac{2}{3}\mathbf{k}\right)\\ &= (-0.5)\left(\frac{1}{3}\right)+(0.8660)\left(\frac{2}{3}\right)+0\left(-\frac{2}{3}\right)\\ &= 0.4107\end{aligned}$$

Then,

$$\phi = \cos^{-1}(\mathbf{u}_{OD}\cdot\mathbf{u}_{OA}) = \cos^{-1}0.4107 = 65.8^\circ \qquad \textbf{Ans}$$

2–126. The cables each exert a force of 400 N on the post. Determine the magnitude of the projected component of $\mathbf{F}_1$ along the line of action of $\mathbf{F}_2$.



Force Vector:

$$\mathbf{u}_{F_1} = \sin 35^\circ \cos 20^\circ \mathbf{i} - \sin 35^\circ \sin 20^\circ \mathbf{j} + \cos 35^\circ \mathbf{k}$$
$$= 0.5390\mathbf{i} - 0.1962\mathbf{j} + 0.8192\mathbf{k}$$

$$\mathbf{F}_1 = F_1 \mathbf{u}_{F_1} = 400(0.5390\mathbf{i} - 0.1962\mathbf{j} + 0.8192\mathbf{k}) \text{ N}$$
$$= \{215.59\mathbf{i} - 78.47\mathbf{j} + 327.66\mathbf{k}\} \text{ N}$$

Unit Vector: The unit vector along the line of action of $\mathbf{F}_2$ is

$$\mathbf{u}_{F_2} = \cos 45^\circ \mathbf{i} + \cos 60^\circ \mathbf{j} + \cos 120^\circ \mathbf{k}$$
$$= 0.7071\mathbf{i} + 0.5\mathbf{j} - 0.5\mathbf{k}$$

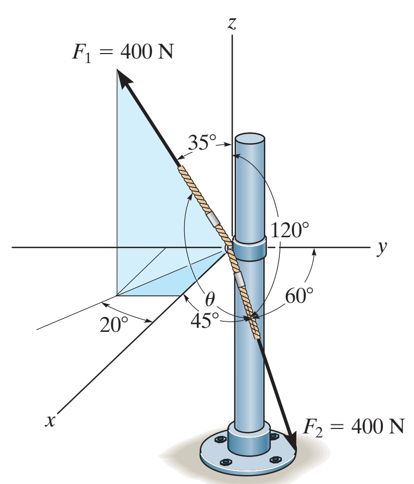
Projected Component of $\mathbf{F}_1$ Along Line of Action of $\mathbf{F}_2$:

$$(F_1)_{F_2} = \mathbf{F}_1 \cdot \mathbf{u}_{F_2} = (215.59\mathbf{i} - 78.47\mathbf{j} + 327.66\mathbf{k}) \cdot (0.7071\mathbf{i} + 0.5\mathbf{j} - 0.5\mathbf{k})$$
$$= (215.59)(0.7071) + (-78.47)(0.5) + (327.66)(-0.5)$$
$$= -50.6 \text{ N}$$

Negative sign indicates that the force component $(\mathbf{F}_1)_{F_2}$ acts in the opposite sense of direction to that of $\mathbf{u}_{F_2}$.

thus the magnitude is $(\mathbf{F}_1)_{F_2} = 50.6$ N **Ans**

2–127. Determine the angle θ between the two cables attached to the post.



Unit Vector:

$$\mathbf{u}_{F_1} = \sin 35^\circ \cos 20^\circ \mathbf{i} - \sin 35^\circ \sin 20^\circ \mathbf{j} + \cos 35^\circ \mathbf{k}$$
$$= 0.5390\mathbf{i} - 0.1962\mathbf{j} + 0.8192\mathbf{k}$$

$$\mathbf{u}_{F_2} = \cos 45^\circ \mathbf{i} + \cos 60^\circ \mathbf{j} + \cos 120^\circ \mathbf{k}$$
$$= 0.7071\mathbf{i} + 0.5\mathbf{j} - 0.5\mathbf{k}$$

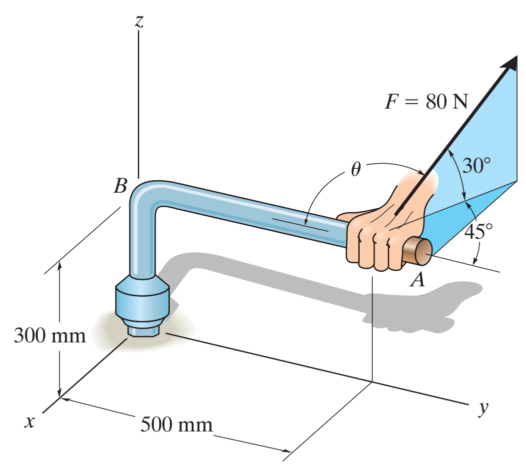
The Angle Between Two Vectors θ: The dot product of two unit vectors must be determined first.

$$\mathbf{u}_{F_1} \cdot \mathbf{u}_{F_2} = (0.5390\mathbf{i} - 0.1962\mathbf{j} + 0.8192\mathbf{k}) \cdot (0.7071\mathbf{i} + 0.5\mathbf{j} - 0.5\mathbf{k})$$
$$= 0.5390(0.7071) + (-0.1962)(0.5) + 0.8192(-0.5)$$
$$= -0.1265$$

Then,

$$\theta = \cos^{-1}\left(\mathbf{u}_{F_1} \cdot \mathbf{u}_{F_2}\right) = \cos^{-1}(-0.1265) = 97.3^\circ \qquad \textbf{Ans}$$

***2–128.** A force of $F = 80$ N is applied to the handle of the wrench. Determine the angle θ between the tail of the force and the handle AB.



$$\mathbf{u}_F = -\cos 30° \sin 45° \mathbf{i} + \cos 30° \cos 45° \mathbf{j} + \sin 30° \mathbf{k}$$

$$= -0.6124\,\mathbf{i} + 0.6124\,\mathbf{j} + 0.5\,\mathbf{k}$$

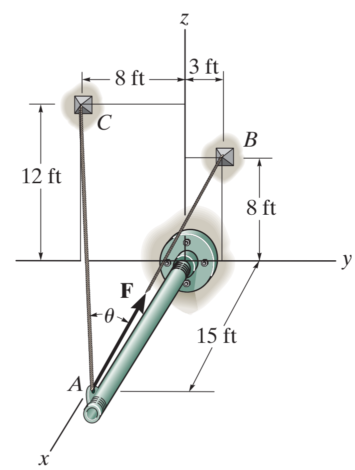
$$\mathbf{u}_{AB} = -\mathbf{j}$$

$$\cos\theta = \mathbf{u}_F \cdot \mathbf{u}_{AB} = (-0.6124\,\mathbf{i} + 0.6124\,\mathbf{j} + 0.5\,\mathbf{k}) \cdot (-\mathbf{j})$$

$$= -0.6124$$

$$\theta = 128° \qquad \textbf{Ans}$$

•2–129. Determine the angle θ between cables AB and AC.



Position Vector :

$$\mathbf{r}_{AB} = \{(0-15)\mathbf{i} + (3-0)\mathbf{j} + (8-0)\mathbf{k}\} \text{ ft}$$
$$= \{-15\mathbf{i} + 3\mathbf{j} + 8\mathbf{k}\} \text{ ft}$$

$$\mathbf{r}_{AC} = \{(0-15)\mathbf{i} + (-8-0)\mathbf{j} + (12-0)\mathbf{k}\} \text{ ft}$$
$$= \{-15\mathbf{i} - 8\mathbf{j} + 12\mathbf{k}\} \text{ ft}$$

The magnitudes of the postion vectors are

$$r_{AB} = \sqrt{(-15)^2 + 3^2 + 8^2} = 17.263 \text{ ft}$$
$$r_{AC} = \sqrt{(-15)^2 + (-8)^2 + 12^2} = 20.809 \text{ ft}$$

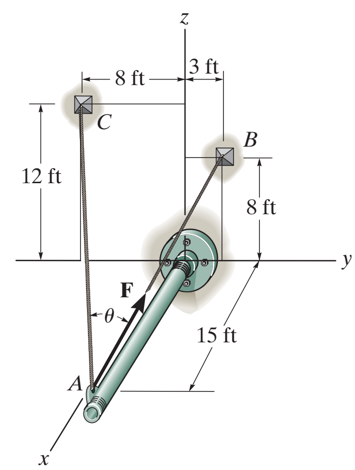
The Angles Between Two Vectors θ:

$$\mathbf{r}_{AB} \cdot \mathbf{r}_{AC} = (-15\mathbf{i} + 3\mathbf{j} + 8\mathbf{k}) \cdot (-15\mathbf{i} - 8\mathbf{j} + 12\mathbf{k})$$
$$= (-15)(-15) + (3)(-8) + 8(12)$$
$$= 297 \text{ ft}^2$$

Then,

$$\theta = \cos^{-1}\left(\frac{\mathbf{r}_{AB} \cdot \mathbf{r}_{AC}}{r_{AB} r_{AC}}\right) = \cos^{-1}\left[\frac{297}{17.263(20.809)}\right] = 34.2° \qquad \textbf{Ans}$$

2–130. If **F** has a magnitude of 55 lb, determine the magnitude of its projected components acting along the x axis and along cable AC.



Force Vector :

$$\mathbf{u}_{AB} = \frac{(0-15)\mathbf{i}+(3-0)\mathbf{j}+(8-0)\mathbf{k}}{\sqrt{(0-15)^2+(3-0)^2+(8-0)^2}}$$
$$= -0.8689\mathbf{i}+0.1738\mathbf{j}+0.4634\mathbf{k}$$

$$\mathbf{F} = F\mathbf{u}_{AB} = 55(-0.8689\mathbf{i}+0.1738\mathbf{j}+0.4634\mathbf{k})\ \text{lb}$$
$$= \{-47.791\mathbf{i}+9.558\mathbf{j}+25.489\mathbf{k}\}\ \text{lb}$$

Unit Vector : The unit vector along negative x axis and AC are

$$\mathbf{u}_x = -1\mathbf{i}$$

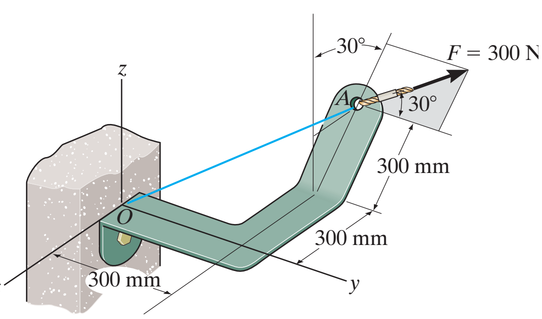
$$\mathbf{u}_{AC} = \frac{(0-15)\mathbf{i}+(-8-0)\mathbf{j}+(12-0)\mathbf{k}}{\sqrt{(0-15)^2+(-8-0)^2+(12-0)^2}}$$
$$= -0.7209\mathbf{i}-0.3845\mathbf{j}+0.5767\mathbf{k}$$

Projected Component of F :

$$F_x = \mathbf{F}\cdot\mathbf{u}_x = (-47.791\mathbf{i}+9.558\mathbf{j}+25.489\mathbf{k})\cdot(-1\mathbf{i})$$
$$= (-47.791)(-1)+9.558(0)+25.489(0)$$
$$= 47.8\ \text{lb} \qquad \textbf{Ans}$$

$$F_{AC} = \mathbf{F}\cdot\mathbf{u}_{AC} = (-47.791\mathbf{i}+9.558\mathbf{j}+25.489\mathbf{k})\cdot(-0.7209\mathbf{i}-0.3845\mathbf{j}+0.5767\mathbf{k})$$
$$= (-47.791)(-0.7209)+(9.558)(-0.3845)+(25.489)(0.5767)$$
$$= 45.5\ \text{lb} \qquad \textbf{Ans}$$

2–131. Determine the magnitudes of the projected components of the force $F = 300$ N acting along the x and y axes.



Force Vector: The force vector **F** must be determined first. From Fig. *a*,

$$\mathbf{F} = -300\sin 30^\circ \sin 30^\circ\mathbf{i} + 300\cos 30^\circ\mathbf{j} + 300\sin 30^\circ\cos 30^\circ\mathbf{k}$$
$$= [-75\mathbf{i} + 259.81\mathbf{j} + 129.90\mathbf{k}]\text{N}$$

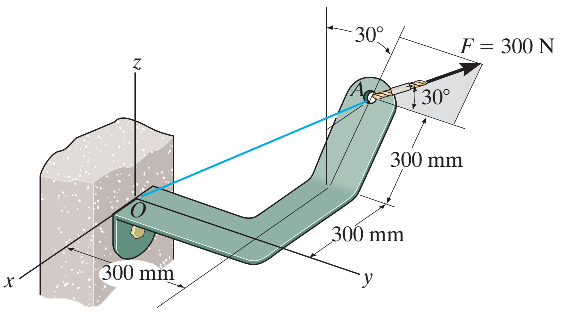
Vector Dot Product: The magnitudes of the projected component of **F** along the x and y axes are

$$F_x = \mathbf{F}\cdot\mathbf{i} = (-75\mathbf{i} + 259.81\mathbf{j} + 129.90\mathbf{k})\cdot\mathbf{i}$$
$$= -75(1) + 259.81(0) + 129.90(0)$$
$$= -75\ \text{N}$$
$$F_y = \mathbf{F}\cdot\mathbf{j} = (-75\mathbf{i} + 259.81\mathbf{j} + 129.90\mathbf{k})\cdot\mathbf{j}$$
$$= -75(0) + 259.81(1) + 129.90(0)$$
$$= 260\ \text{N}$$

The negative sign indicates that $\mathbf{F}_x$ is directed towards the negative x axis. Thus

$$F_x = 75\ \text{N}, \quad F_y = 260\ \text{N} \qquad \textbf{Ans.}$$

***2–132.** Determine the magnitude of the projected component of the force $F = 300$ N acting along line OA.



Force and unit Vector: The force vector **F** and unit vector $\mathbf{u}_{OA}$ must be determined first. From Fig. (a)

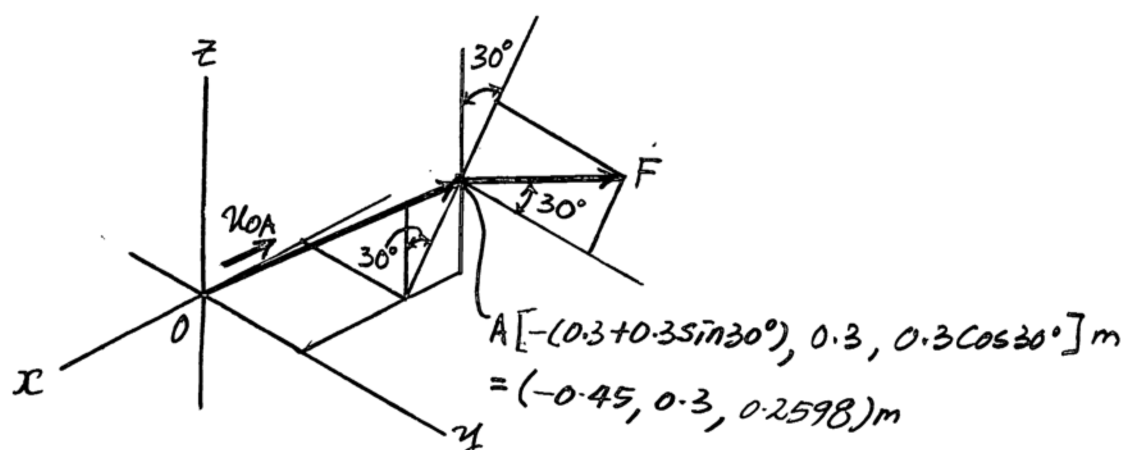
$$\mathbf{F} = -300\sin 30°\sin 30°\mathbf{i} + 300\cos 30°\mathbf{j} + 300\sin 30°\cos 30°\mathbf{k})$$
$$= \{-75\mathbf{i} + 259.81\mathbf{j} + 129.90\mathbf{k}\}\text{N}$$

$$\mathbf{u}_{OA} = \frac{\mathbf{r}_{OA}}{r_{OA}} = \frac{(-0.45-0)\mathbf{i} + (0.3-0)\mathbf{j} + (0.2598-0)\mathbf{k}}{\sqrt{(-0.45-0)^2 + (0.3-0)^2 + (0.2598-0)^2}} = -0.75\mathbf{i} + 0.5\mathbf{j} + 0.4330\mathbf{k}$$

Vector Dot Product: The magnitude of the projected component of **F** along line OA is

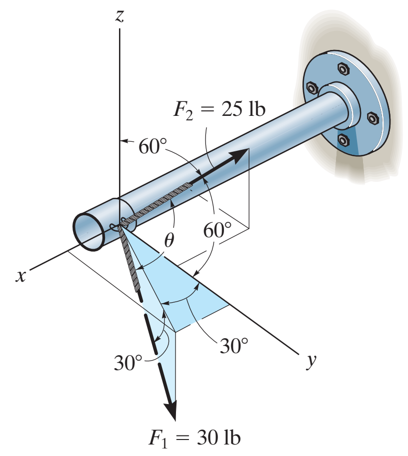
$$F_{OA} = \mathbf{F}\cdot\mathbf{u}_{OA} = (-75\mathbf{i} + 259.81\mathbf{j} + 129.90\mathbf{k})\cdot(-0.75\mathbf{i} + 0.5\mathbf{j} + 0.4330\mathbf{k})$$
$$= (-75)(-0.75) + 259.81(0.5) + 129.90(0.4330)$$
$$= 242\text{ N}$$

Ans.



(a)

•**2–133.** Two cables exert forces on the pipe. Determine the magnitude of the projected component of $\mathbf{F}_1$ along the line of action of $\mathbf{F}_2$.



Force Vector:

$$\mathbf{u}_{F_1} = \cos 30°\sin 30°\mathbf{i} + \cos 30°\cos 30°\mathbf{j} - \sin 30°\mathbf{k}$$
$$= 0.4330\mathbf{i} + 0.75\mathbf{j} - 0.5\mathbf{k}$$

$$\mathbf{F}_1 = F_1\mathbf{u}_{F_1} = 30(0.4330\mathbf{i} + 0.75\mathbf{j} - 0.5\mathbf{k})\text{ lb}$$
$$= \{12.990\mathbf{i} + 22.5\mathbf{j} - 15.0\mathbf{k}\}\text{ lb}$$

Unit Vector: One can obtain the angle $\alpha = 135°$ for $\mathbf{F}_2$ using Eq. 2–8. $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$, with $\beta = 60°$ and $\gamma = 60°$. The unit vector along the line of action of $\mathbf{F}_2$ is

$$\mathbf{u}_{F_2} = \cos 135°\mathbf{i} + \cos 60°\mathbf{j} + \cos 60°\mathbf{k} = -0.7071\mathbf{i} + 0.5\mathbf{j} + 0.5\mathbf{k}$$

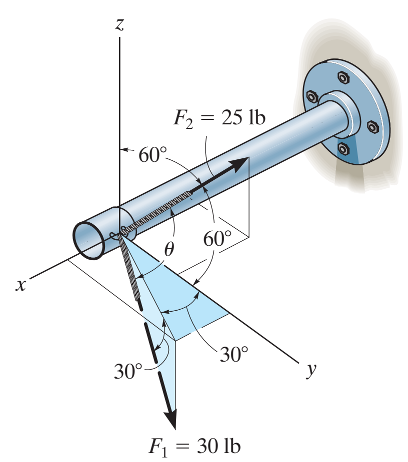
Projected Component of $\mathbf{F}_1$ Along the Line of Action of $\mathbf{F}_2$:

$$(F_1)_{F_2} = \mathbf{F}_1 \cdot \mathbf{u}_{F_2} = (12.990\mathbf{i} + 22.5\mathbf{j} - 15.0\mathbf{k}) \cdot (-0.7071\mathbf{i} + 0.5\mathbf{j} + 0.5\mathbf{k})$$
$$= (12.990)(-0.7071) + (22.5)(0.5) + (-15.0)(0.5)$$
$$= -5.44\text{ lb}$$

Negative sign indicates that the projected component $(\mathbf{F}_1)_{F_2}$ acts in the opposite sense of direction to that of $\mathbf{u}_{F_2}$.

The magnitude is $(F_1)_{F_2} = 5.44$ lb. **Ans**

2–134. Determine the angle θ between the two cables attached to the pipe.



Unit Vector:

$$\mathbf{u}_{F_1} = \cos 30°\sin 30°\mathbf{i} + \cos 30°\cos 30°\mathbf{j} - \sin 30°\mathbf{k}$$
$$= 0.4330\mathbf{i} + 0.75\mathbf{j} - 0.5\mathbf{k}$$

$$\mathbf{u}_{F_2} = \cos 135°\mathbf{i} + \cos 60°\mathbf{j} + \cos 60°\mathbf{k}$$
$$= -0.7071\mathbf{i} + 0.5\mathbf{j} + 0.5\mathbf{k}$$

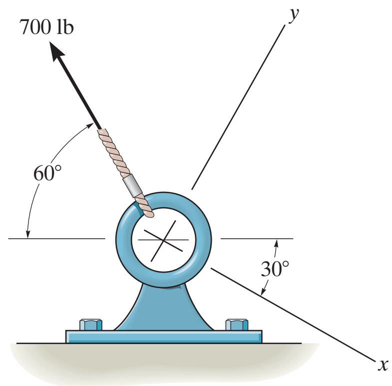
The Angles Between Two Vectors θ:

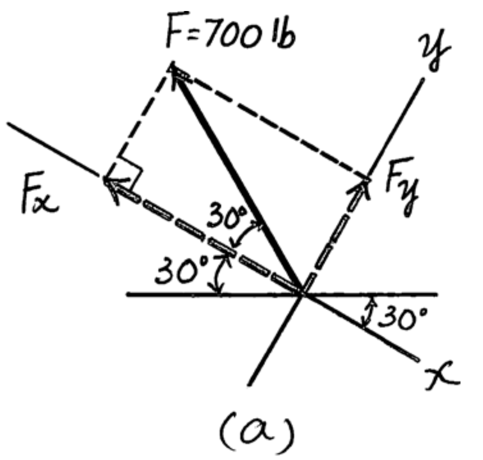
$$\mathbf{u}_{F_1} \cdot \mathbf{u}_{F_2} = (0.4330\mathbf{i} + 0.75\mathbf{j} - 0.5\mathbf{k}) \cdot (-0.7071\mathbf{i} + 0.5\mathbf{j} + 0.5\mathbf{k})$$
$$= 0.4330(-0.7071) + 0.75(0.5) + (-0.5)(0.5)$$
$$= -0.1812$$

Then,

$$\theta = \cos^{-1}(\mathbf{u}_{F_1} \cdot \mathbf{u}_{F_2}) = \cos^{-1}(-0.1812) = 100° \quad \textbf{Ans}$$

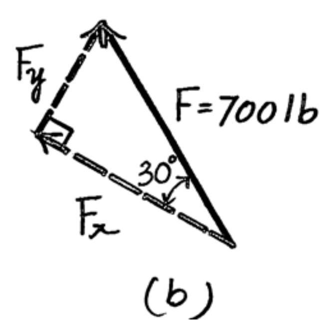
2–135. Determine the x and y components of the 700-lb force.



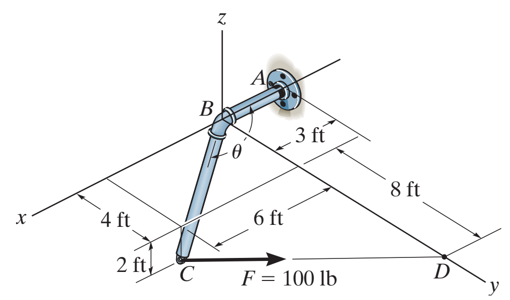


$F_x = -700 \cos 30° = -606$ lb **Ans**

$F_y = 700 \sin 30° = 350$ lb **Ans**



***2–136.** Determine the magnitude of the projected component of the 100-lb force acting along the axis *BC* of the pipe.



Force Vector :

$$\mathbf{u}_{CD} = \frac{(0-6)\mathbf{i}+(12-4)\mathbf{j}+[0-(-2)]\mathbf{k}}{\sqrt{(0-6)^2+(12-4)^2+[0-(-2)]^2}}$$
$$= -0.5883\mathbf{i}+0.7845\mathbf{j}+0.1961\mathbf{k}$$

$$\mathbf{F} = F\mathbf{u}_{CD} = 100(-0.5883\mathbf{i}+0.7845\mathbf{j}+0.1961\mathbf{k})$$
$$= \{-58.835\mathbf{i}+78.446\mathbf{j}+19.612\mathbf{k}\}\ \text{lb}$$

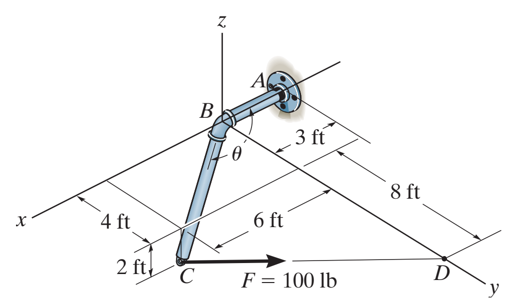
Unit Vector : The unit vector along *CB* is

$$\mathbf{u}_{CB} = \frac{(0-6)\mathbf{i}+(0-4)\mathbf{j}+[0-(-2)]\mathbf{k}}{\sqrt{(0-6)^2+(0-4)^2+[0-(-2)]^2}}$$
$$= -0.8018\mathbf{i}-0.5345\mathbf{j}+0.2673\mathbf{k}$$

Projected Component of F Along CB :

$$F_{CB} = \mathbf{F}\cdot\mathbf{u}_{CB} = (-58.835\mathbf{i}+78.446\mathbf{j}+19.612\mathbf{k})\cdot(-0.8018\mathbf{i}-0.5345\mathbf{j}+0.2673\mathbf{k})$$
$$= (-58.835)(-0.8018)+(78.446)(-0.5345)+(19.612)(0.2673)$$
$$= 10.5\ \text{lb} \qquad \textbf{Ans}$$

•2–137. Determine the angle θ between pipe segments *BA* and *BC*.



Position Vector :

$$\mathbf{r}_{BA} = \{-3\mathbf{i}\}\ \text{ft}$$

$$\mathbf{r}_{BC} = \{(6-0)\mathbf{i}+(4-0)\mathbf{j}+(-2-0)\mathbf{k}\}\ \text{ft}$$
$$= \{6\mathbf{i}+4\mathbf{j}-2\mathbf{k}\}\ \text{ft}$$

The magnitudes of the position vectors are

$$r_{BA} = 3.00\ \text{ft} \qquad r_{BC} = \sqrt{6^2+4^2+(-2)^2} = 7.483\ \text{ft}$$

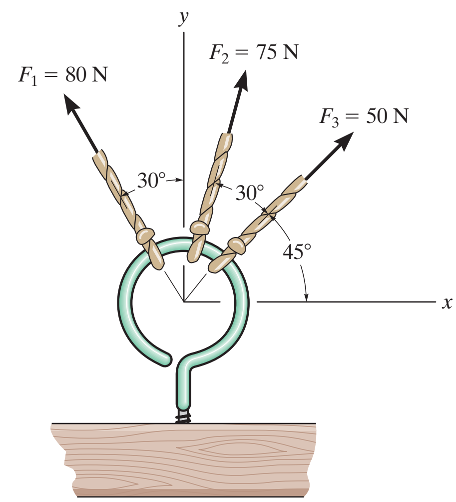
The Angle Between Two Vectors θ :

$$\mathbf{r}_{BA}\cdot\mathbf{r}_{BC} = (-3\mathbf{i})\cdot(6\mathbf{i}+4\mathbf{j}-2\mathbf{k})$$
$$= (-3)(6)+(0)(4)+0(-2)$$
$$= -18.0\ \text{ft}^2$$

Then,

$$\theta = \cos^{-1}\left(\frac{\mathbf{r}_{BA}\cdot\mathbf{r}_{BC}}{r_{BA}r_{BC}}\right) = \cos^{-1}\left[\frac{-18.0}{3.00(7.483)}\right] = 143° \qquad \textbf{Ans}$$

2–138. Determine the magnitude and direction of the resultant $\mathbf{F}_R = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3$ of the three forces by first finding the resultant $\mathbf{F}' = \mathbf{F}_1 + \mathbf{F}_3$ and then forming $\mathbf{F}_R = \mathbf{F}' + \mathbf{F}_2$. Specify its direction measured counterclockwise from the positive x axis.



$$F' = \sqrt{(80)^2 + (50)^2 - 2(80)(50)\cos 105^\circ} = 104.7\text{ N}$$

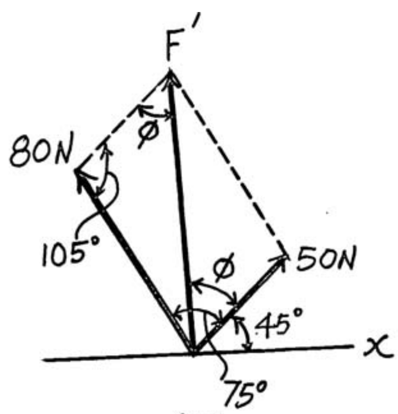
$$\frac{\sin\phi}{80} = \frac{\sin 105^\circ}{104.7}; \quad \phi = 47.54^\circ$$

$$F_R = \sqrt{(104.7)^2 + (75)^2 - 2(104.7)(75)\cos 162.46^\circ}$$

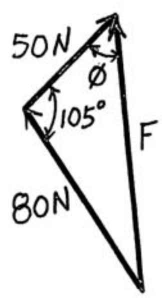
$$F_R = 177.7 = 178\text{ N} \qquad \textbf{Ans}$$

$$\frac{\sin\beta}{104.7} = \frac{\sin 162.46^\circ}{177.7}; \quad \beta = 10.23^\circ$$

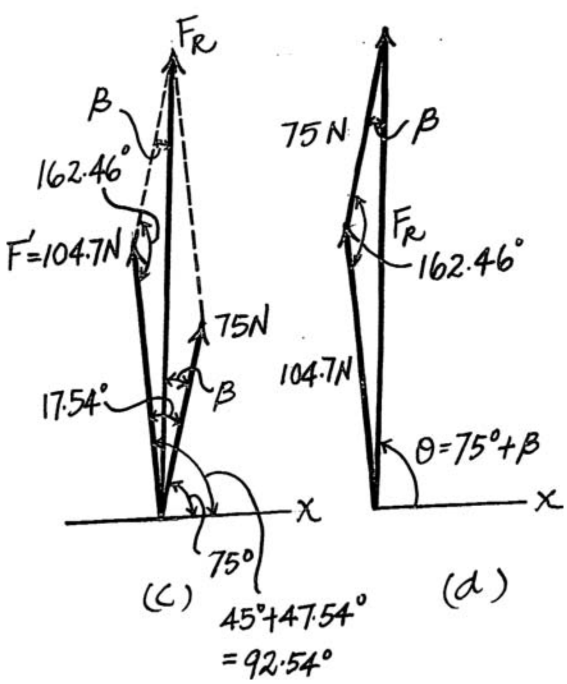
$$\theta = 75^\circ + 10.23^\circ = 85.2^\circ \qquad \textbf{Ans}$$



(a)

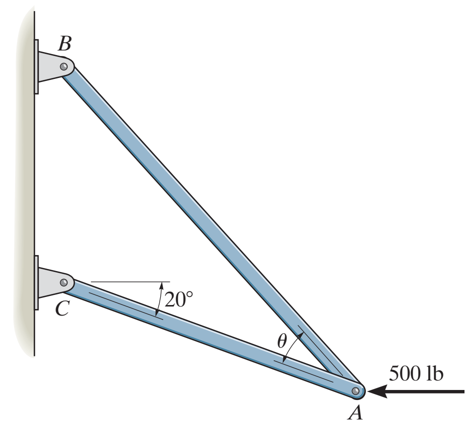


(b)

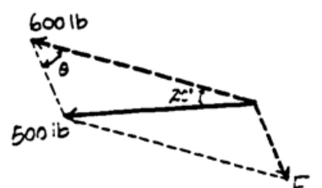


(c) (d)

2–139. Determine the design angle θ ($\theta < 90°$) between the two struts so that the 500-lb horizontal force has a component of 600 lb directed from A toward C. What is the component of force acting along member BA?



The parallelogram law of addition and the triangular rule are shown in Figs. *a* and *b*.



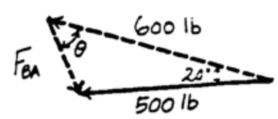
(a)

Applying the law of cosines to Fig. *b*,

$$F_R = \sqrt{500^2 + 600^2 - 2(500)(600)\cos 20°}$$
$$= 214.91 \text{ lb} = 215 \text{ lb} \qquad \textbf{Ans.}$$

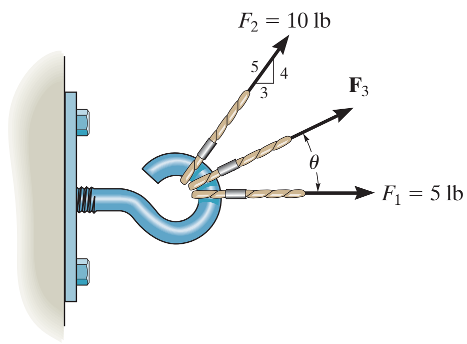
Applying the law of sines to Fig. *b* and using this result yields

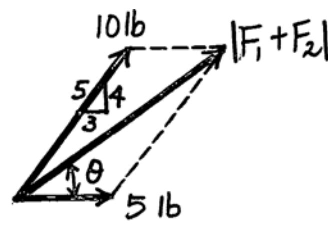
$$\frac{\sin\theta}{500} = \frac{\sin 20°}{214.91} \qquad \theta = 52.7° \qquad \textbf{Ans.}$$



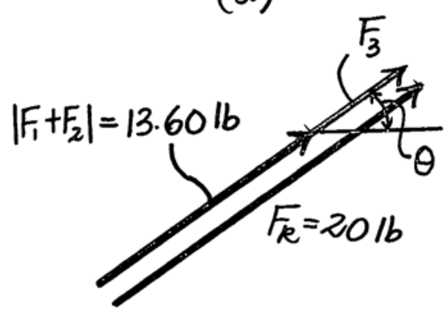
(b)

***2–140.** Determine the magnitude and direction of the *smallest* force $\mathbf{F}_3$ so that the resultant force of all three forces has a magnitude of 20 lb.





(a)



(b)

F_3 is minimum :

$$F_3 = 20 - |F_1 + F_2|$$

$$F_1 + F_2 = \left(5 + 10\left(\frac{3}{5}\right)\right)\mathbf{i} + \left(10\left(\frac{4}{5}\right)\right)\mathbf{j} = 11\,\mathbf{i} + 8\,\mathbf{j}$$

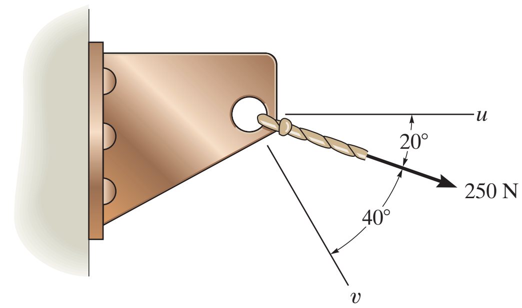
$$|F_1 + F_2| = \sqrt{11^2 + 8^2} = 13.601 \text{ lb}$$

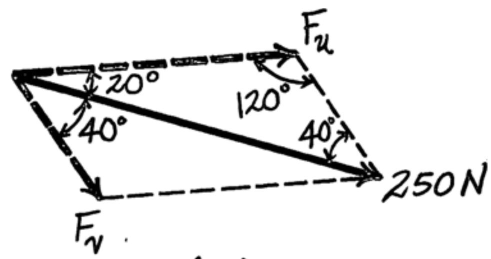
$$\theta = \tan^{-1}\left(\frac{8}{11}\right) = 36.0^\circ \qquad \text{Ans}$$

Thus

$$(F_3)_{min} = 20 - 13.601 = 6.40 \text{ lb} \qquad \text{Ans}$$

•2–141. Resolve the 250-N force into components acting along the u and v axes and determine the magnitudes of these components.

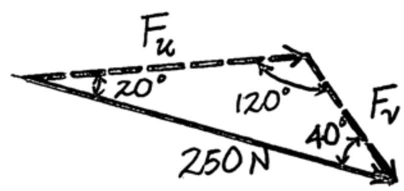




(a)

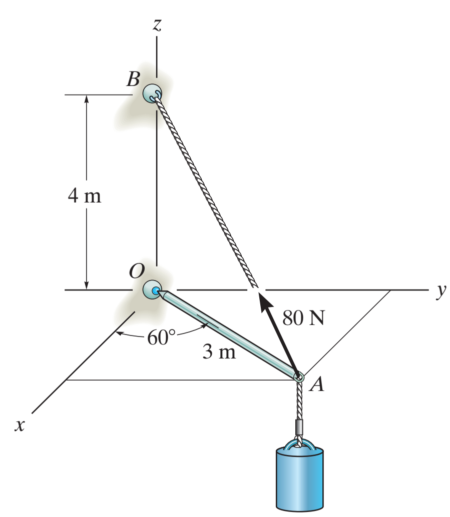
$$\frac{250}{\sin 120°} = \frac{F_u}{\sin 40°}; \qquad F_u = 186 \text{ N} \qquad \text{Ans}$$

$$\frac{250}{\sin 120°} = \frac{F_v}{\sin 20°}; \qquad F_v = 98.7 \text{ N} \qquad \text{Ans}$$



(b)

2–142. Cable AB exerts a force of 80 N on the end of the 3-m-long boom OA. Determine the magnitude of the projection of this force along the boom.



Vector Analysis :

$$\mathbf{F} = 80\left(\frac{\mathbf{r}_{AB}}{r_{AB}}\right) = 80\left(-\frac{3\cos 60°}{5}\,\mathbf{i} - \frac{3\sin 60°}{5}\,\mathbf{j} + \frac{4}{5}\,\mathbf{k}\right)$$

$$= -24\,\mathbf{i} - 41.57\,\mathbf{j} + 64\,\mathbf{k}$$

$$\mathbf{u}_{AO} = -\cos 60°\,\mathbf{i} - \sin 60°\,\mathbf{j} = -0.5\,\mathbf{i} - 0.866\,\mathbf{j}$$

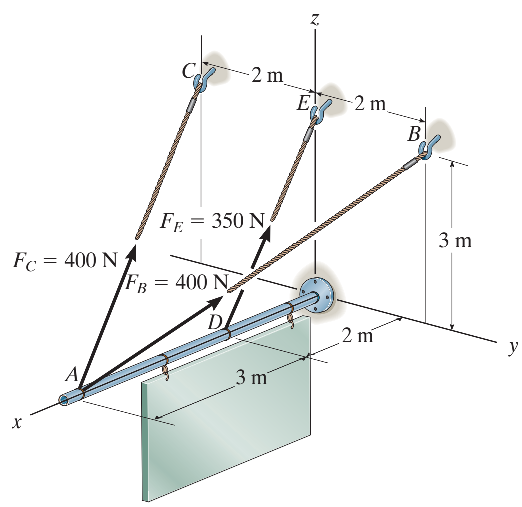
$$\text{Proj}\,F = \mathbf{F}\cdot\mathbf{u}_{AO} = (-24)(-0.5) + (-41.57)(-0.866) + (64)0 = 48.0 \text{ N} \qquad \text{Ans}$$

Scalar Anaysis :

$$\text{Angle } OAB = \tan^{-1}\left(\frac{4}{3}\right) = 53.13°$$

$$\text{Proj}\,F = 80\cos 53.13° = 48.0 \text{ N} \qquad \text{Ans}$$

2–143. The three supporting cables exert the forces shown on the sign. Represent each force as a Cartesian vector.



Unit Vector:

$$\mathbf{r}_{AB} = \{(0-5)\mathbf{i} + (2-0)\mathbf{j} + (3-0)\mathbf{k}\}\ \text{m} = \{-5\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}\}\ \text{m}$$
$$r_{AB} = \sqrt{(-5)^2 + 2^2 + 3^2} = 6.164\ \text{m}$$
$$\mathbf{u}_{AB} = \frac{\mathbf{r}_{AB}}{r_{AB}} = \frac{-5\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}}{6.164} = -0.8111\mathbf{i} + 0.3244\mathbf{j} + 0.4867\mathbf{k}$$

$$\mathbf{r}_{AC} = \{(0-5)\mathbf{i} + (-2-0)\mathbf{j} + (3-0)\mathbf{k}\}\ \text{m} = \{-5\mathbf{i} - 2\mathbf{j} + 3\mathbf{k}\}\ \text{m}$$
$$r_{AC} = \sqrt{(-5)^2 + (-2)^2 + 3^2} = 6.164\ \text{m}$$
$$\mathbf{u}_{AC} = \frac{\mathbf{r}_{AC}}{r_{AC}} = \frac{-5\mathbf{i} - 2\mathbf{j} + 3\mathbf{k}}{6.164} = -0.8111\mathbf{i} - 0.3244\mathbf{j} + 0.4867\mathbf{k}$$

$$\mathbf{r}_{DE} = \{(0-2)\mathbf{i} + (0-0)\mathbf{j} + (3-0)\mathbf{k}\}\ \text{m} = \{-2\mathbf{i} + 3\mathbf{k}\}\ \text{m}$$
$$r_{DE} = \sqrt{(-2)^2 + 3^2} = 3.605\ \text{m}$$
$$\mathbf{u}_{DE} = \frac{\mathbf{r}_{DE}}{r_{DE}} = \frac{-2\mathbf{i} + 3\mathbf{k}}{3.605} = -0.5547\mathbf{i} + 0.8321\mathbf{k}$$

Force Vector:

$$\mathbf{F}_B = F_B\mathbf{u}_{AB} = 400\{-0.8111\mathbf{i} + 0.3244\mathbf{j} + 0.4867\mathbf{k}\}\ \text{N}$$
$$= \{-324.44\mathbf{i} + 129.78\mathbf{j} + 194.67\mathbf{k}\}\ \text{N}$$
$$= \{-324\mathbf{i} + 130\mathbf{j} + 195\mathbf{k}\}\ \text{N} \qquad \textbf{Ans}$$

$$\mathbf{F}_C = F_C\mathbf{u}_{AB} = 400\{-0.8111\mathbf{i} - 0.3244\mathbf{j} + 0.4867\mathbf{k}\}\ \text{N}$$
$$= \{-324.44\mathbf{i} - 129.78\mathbf{j} + 194.67\mathbf{k}\}\ \text{N}$$
$$= \{-324\mathbf{i} - 130\mathbf{j} + 195\mathbf{k}\}\ \text{N} \qquad \textbf{Ans}$$

$$\mathbf{F}_E = F_E\mathbf{u}_{DE} = 350\{-0.5547\mathbf{i} + 0.8321\mathbf{k}\}\ \text{N}$$
$$= \{-194.15\mathbf{i} + 291.22\mathbf{k}\}\ \text{N}$$
$$= \{-194\mathbf{i} + 291\mathbf{k}\}\ \text{N} \qquad \textbf{Ans}$$